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EXPLANA-

EXPLANATION OF THE PLATES

in Vol. II.

P L A T E I.

- FIG. 1. Thigh Bone of the Elephant at Versailles.
 FIG. 2. Thigh Bone of the Animal Incognitum of Canada.
 FIG. 3. Thigh Bone of the Animal Incognitum of Siberia.
 FIG. 4. Posterior View of the Thigh Bone belonging to Mr. White.
 FIG. 5. Anterior View of the Thigh Bone belonging to Mr. White.
 FIG. 6. Jaw Bone of the Animal Incognitum.
 FIG. 7. Jaw Bone of the Elephant.
 FIG. 8. An Instrument for measuring the Specific Gravity of Bodies, described page 390.

P L A T E II.

Apparatus for impregnating Wort and other fermentable Liquors with Fixed Air.

- FIG. 1. A A The Cask in which the Wort is to be impregnated.
 (d d) The Strings by which the Vessel is to be let down.
 (e e) The Pegs to which the Strings are to be fastened.
 FIG. 2. D D The Air Vessel, similar to the bottom Part of Dr. Nooth's Glass Machine, to be made of Glass or Earthen Ware.
 (c c) A Glass Stopper, ground in to fit the Mouth of the Vessel, having a Number of Capillary Tubes running from bottom to top in a diverging Direction, so as to spread the Air in its Passage through the Liquor.
 FIG. 3. The Stopper viewed separately to shew its Capillary Tubes.



Fig.1

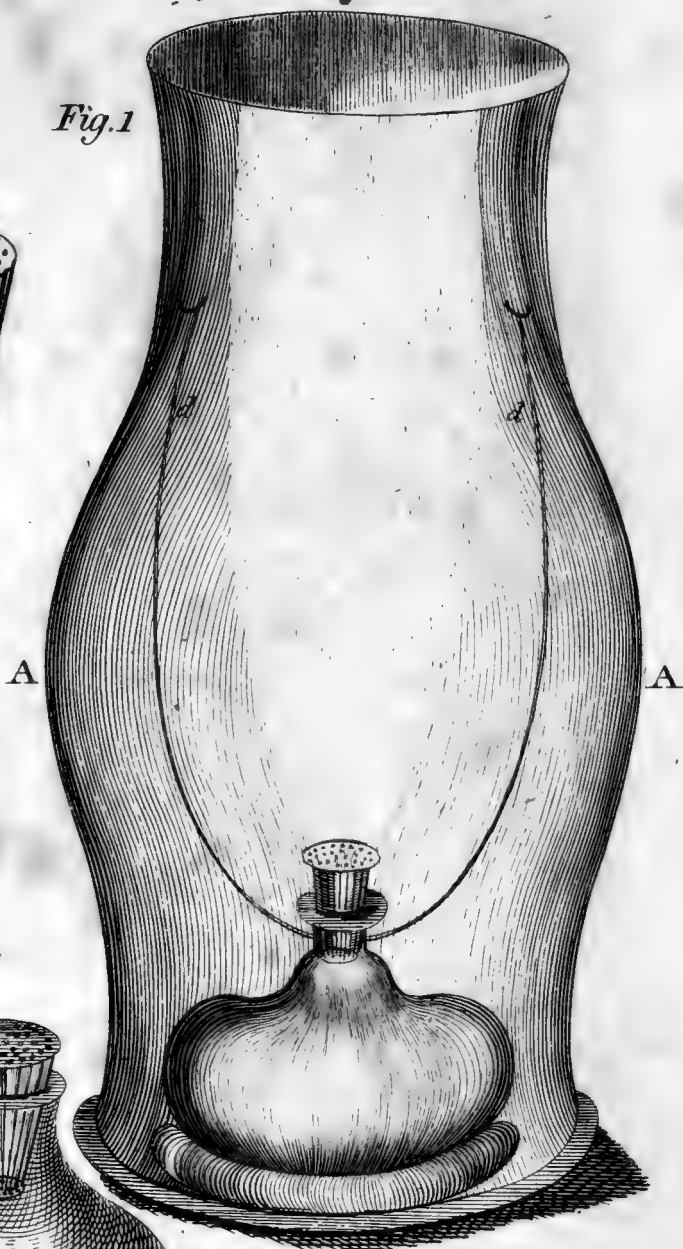


Fig.3



Fig.2



M E M O I R S

OF THE

LITERARY AND PHILOSOPHICAL SOCIETY OF MANCHESTER.

*A brief COMPARISON of some of the principal
ARGUMENTS in Favour of PUBLIC and PRIVATE
EDUCATION. By THOMAS BARNES, D. D.
Read May 7, 1783.*

THERE are few questions more important, when considered in every point of view, than those which relate to EDUCATION. Allowing the original differences stamped upon human minds to be great, yet education marks far greater and stronger lines of distinction, between one mind and another. It was education, which formed the polished and lettered sage, in the æra of the highest Grecian splendour. And it is education, which moulds the savage Indian for the desert.

“ Dii Immortales !” Homini Homo quid præstat !
 Stulto intelligens ! Quid interest ! *

It is generally said, in praise of the present age, that it is more sensible, than any which have preceded, of the immense importance of education. I mean not to detract from the real merit of my cotemporaries, by hinting a suspicion, that something must be abated of this high compliment. The *object* and *end*, upon which modern education is often employed, will not, I fear, do the greatest honour to our discernment, or our piety.

Among the various plans of education, each of which has had its warm admirers, and sanguine advocates, the parent, anxiously interested for the best welfare of his son, (for I wish to confine the present subject to boys,) is often greatly at a loss which to prefer. There are, probably, advantages and disadvantages peculiar to every system. The point to be wished for, is, to balance these so justly, one against another, as to form the proper conclusion.

There are not a few, both in antient and modern times, who contend earnestly for a PUBLIC scheme of education. There are others, perhaps an equal number, who object as earnestly *against* it. We must imagine the general views of those, who embrace the opposite sides of

* Terence Eun. Act. II. Sec. 2.

this question, to be exactly the same. But, they consider the several schemes, in different aspects.

I have not the vanity to hope, that I shall be able to offer a single argument, which has not been repeatedly canvassed. My utmost wish, in chusing this subject, was, not to offer something new; but to throw out a few hints, merely by way of introducing a question, than which none greater and more interesting has been, or, by our laws, can be agitated in these meetings.

That we may speak with precision on this subject, it will be necessary to define the terms, PUBLIC and PRIVATE education.

By PUBLIC EDUCATION, we mean, education at a large public school, consisting of perhaps two or three hundred boys, such as ETON or WESTMINSTER; where the boys live in some common apartments, destined for this use, or are boarded in great numbers, with persons, who only undertake to find them commons and accommodation.

By PRIVATE EDUCATION, we mean, education AT HOME, in the house, and under the eye of a parent, or private tutor.

Between these two schemes, there will be almost infinite gradations. Exactly in the midway between them, are those schools, where boys are boarded in the house of a master,

4 *Dr. Barnes on Public and Private Education.*

become parts of his family, and are not more in number, than he can entirely manage and instruct himself.

We may, perhaps class the prime objects of education, in the following order, beginning with those of less importance, and rising up to those of the greatest. HEALTH—KNOWLEDGE—TEMPER—SELF-GOVERNMENT—MORALS.

I. HEALTH.

It is questioned, whether the carelessness, which must necessarily prevail in a large public school, with respect to the several articles of diet, lodging, dampness, &c.—or the constant careful attention paid to all these circumstances, in the house of a parent, be more friendly to health, and vigour of constitution. It is said, “That an excess of caution injures both the body and the mind, rendering the one puny, and the other pusillanimous.” It is added, “That, in a large number of boys, there are more incitements to play, and to those active athletic exercises, which brace the system, and render it robust and hardy.”

It must be acknowledged, that the closeness of a nursery is unfriendly to the constitution. But why must we necessarily suppose a boy to be confined to a nursery, in his father's house? May he not be accustomed, *at home*, to any degree of hardness, at the pleasure of the parent

parent? And are not the principles and conduct of parents, in fact very different? Nor will sufficient incitements to play be wanting, if properly attended to, and improved.

With respect to health, then, a boy *may* have all the advantages, without the many disadvantages, attending a more public plan. And, from what I have observed of life, I should be ready to conclude, that children, who have been educated upon the system of extreme carelessness, in these particulars, have not appeared more vigorous and healthy, when they have grown to maturity.

II. KNOWLEDGE.

It is urged, in favour of public education, "That emulation, that strong and noble principle, when well managed, is more likely to be felt in its proper influence, where there are many, than where there are few competitors. The numbers, and the abilities of the candidates sharpen the edge of genius and of industry, and thus push on the youthful mind to superior excellence."

It may, perhaps, be said, on the other hand, "That to the boy of more brilliant parts, and who stands at the head of his class, the argument from emulation may be allowed. But, that these will be comparatively few; and that to others, who are not able to attain this honour-

able elevation, it will be reversed, for that its influence will tend to discouragement and depression." It may be added, "That, in large schools, boys are necessarily connected together in classes, like horses in a carriage; that they cannot move on beyond a certain pace; and that this pace must be accommodated to the parts and quickness of the most indolent and stupid in the class; or else, it will be, for one boy in the class too quick, and for another, too slow. The consequence will be almost equally prejudicial to both. The one is pushed forward beyond his speed; he is liable to be continually punished for no fault; or hurried on through subjects, of which he has not been able to gain any clear and competent knowledge. The other is kept down from those attainments, to which he might otherwise have ascended. This constant and wretched clog, it may be said, will be prevented, by having every boy to stand single; or, at least, by matching boys of equal capacity together, who may thus be urged forward exactly according to their strength, neither dejected by the superior genius of one, nor fettered by the greater dullness of another."

To these arguments it may, I think, with great force, be added, "That, in a very large number of boys, there will always be as many, or more, of those who do not excel, as of those who

who do. If, therefore, the one may be supposed to animate, or to asshame, the other may, with equal truth, be supposed to keep those in countenance, whose abilities are not so bright, or whose industry is not so unremitting."

In vindication of the order, which I have assigned to KNOWLEDGE, it may be observed, that the great end of mental cultivation is, to give that exercise and habit to the various powers of the mind, which may enable them to act hereafter, in all the affairs of human life, with the greatest advantage. It is not merely, the *quantity* of ideas acquired, but the *ability* obtained by the soul, of thinking, reasoning, and determining rightly, in every event of the changeful scene, which is of the greatest importance.*

III. TEMPER.

Or, perhaps, more properly SOCIAL AFFECTIONS.

It may be urged, by the advocates for PRIVATE schools, "That there the heart is longer under the influence of the softer and more domestic feelings—That reverence to parents, and love to brothers, sisters, and other relations, is there in continual habit—That on these mild and ten-

* "Leotychides interrogatus, quid potissimum oportet pueros ingenuos discere! Quæ illis, inquit, ubi ad virilem ætatem pervenerint, usui sunt futura." Cicero.

der charities of life, the temper, and the comfort of mankind chiefly depend—And, that, in a public school, these amiable scions of the soul have not room to shoot, but must, of necessity, be miserably neglected.”

If to this argument it be answered, “That in a PUBLIC education there will be partialities and attachments formed :” it may be replied, “That these are not of exactly the same nature, nor will they have the same influence, on future temper and future happiness.”

It will, perhaps, be said, “That in larger schools, connections and friendships may be formed, which may be of the most lasting, honourable, and advantageous tendency in future life.”

This advantage appears to me to be a very precarious one. Early connections between a richer and a poorer boy, founded, probably, on caprice on the one hand, and abject obsequiousness on the other, seldom continue long. Sometimes indeed an honourable union of equals may lay a foundation for future friendship, of the most endeared and permanent nature. And it is possible, that some instances may have occurred, of friendships formed, between youths whose fortunes were unequal, which have been as beneficial to the one, as honourable to the other. But, as boys are often separated at so early an age, and dispersed into such different scenes and regions,

regions, the hope of this ought not to be allowed much weight. And fact will, I persuade myself, bear witness to very few instances of this kind; too few, to give any great degree of force to this argument.

IV. SELF-GOVERNMENT.

By this term is meant, "The habit which, the friends of PUBLIC EDUCATION say, a boy early forms, in a large school, of conducting himself, of managing his own concerns, and of preparing himself for a steady, independent, manly line of action in future life. Such a school they describe as, "a miniature of the great world." And in this microcosm a boy is inured, to make his own way, to stand upon his own merit, to exert his own understanding and address, to maintain his own cause and his own consequence, to fight his own battle, to vindicate his own wrong, and to depend upon his own conduct and character, for the behaviour he meets with. In this society, it is said, all distinctions are levelled. The son of a nobleman appears as an equal to the son of a peasant. Insignificance, ill-temper, folly selfishness, together with the common vices of children (the seeds of similar and stronger vices in men) are discountenanced and discouraged, when they are sure to meet with contempt and hatred. And here, those public spirited and manly virtues grow best, which only can secure the general honour and approbation."

It is possible, that something must be deducted from this flattering representation. In these little republics, some active and bolder spirits, distinguished, probably, for strength and daring, rather than for morals, or literary excellence, gain an ascendancy over the rest. The other boys act under them, in servile submission to their mandate, carry their burdens, fight their battles, and avenge their quarrels. Hence are learnt habits of fawning and servility. Obedience must be unreserved, under penalty of severe chastisement for rebellion. To crouch, in order to obtain the good graces of one of these leaders of a clan, will probably be the policy of a younger, and more timid boy. And he will obtain notice and protection, only by flattery, or submission the most humiliating. The consequence often is, that when he himself rises up to that degree of strength, which enables him to assert his own consequence, he practises all the arts assumed by his former tyrant. And thus, a system of vassalage is handed down, from generation to generation. May it not be said, that all this is as likely to produce abjectness of mind as independence; and turbulence, as proper subordination?

V. M O R A L S.

The *greatest* object of education is, undoubtedly, to inspire the love of goodness. But here, the
argument

argument seems very greatly to preponderate against the plan of public schools. And yet to this point, as to the all-animating center, should every thing else be directed, and, by its tendency to this, should every scheme be estimated. It would be a dreadful bargain, to give up morals for learning, or for any other accomplishment.*

It cannot be denied, that there is certainly far greater danger of moral infection in a larger, than in a smaller number of boys. A single boy may corrupt many, and disseminate a poison, of the most rank and baneful influence. It is impossible, where the numbers are so large, to give that minute and watchful attention to the discipline of the passions, and to the formation of the heart, which is so unspeakably necessary in a good education. Boys, of a depraved turn of mind, have often an unlucky kind of wit, a something in their *manner*, which enables them to do irreparable mischief.

It is acknowledged, by a very ingenious and able advocate for public schools, † that the argument from morals lies undeniably against them. But this effect he ascribes—to the neglect of education at home, before they

* “Nos liberalibus studiis et disciplinis filios erudimus; non quia virtutem dare possunt; sed quia animum ad accipiendam virtutem præparant.” Cic.

† KNOX.

come to school—and to the general dissipation of the age, to which even schools themselves, which ought to be the nurseries of better principles and better manners, too frequently accommodate themselves.

If the fact be granted, that morals are in greater danger in a public, than a private school, this will be, with many parents, a conclusive argument. Boys too soon, too easily receive the alarming contagion. And, when it is once received, it contaminates the whole mass of the soul, and spreads its deadly poison through every future stage of life.

It is however, contended, "That boys, im-mured within the precincts of a private family, are often but ill prepared to stand the shock of future temptation; that they frequently rush, from the extreme of confinement, to the extreme of dissipation, or dissoluteness; and thus, atone for former restraint, by future extravagance."

This may have been the case, where the confinement has been impolitic, or excessive. But, as this is not necessarily attendant upon the private plan, it cannot be admitted as an universal argument against it.

It is to be regretted, that schools, in general, of almost every description, pay so little attention to the culture of the heart; though this is, in comparison with all others, an object, so infinitely superior, that no embellishments

of

of science, no advantages whatever, of any other kind, deserve a moment's regard, without it.

And it is, perhaps, equally to be regretted, that so few parents are proper to have the sole direction and management of their own children. *

It is far more easy to form the theoretic idea of a school, which you might call "THE SCHOOL OF VIRTUE AND OF SCIENCE," than to realize it in action. And yet, I fear, that many parents would not approve of even *this school*, if it were not likewise, "THE SCHOOL OF SHEWY ACCOMPLISHMENTS," which, with many, are of far greater moment, than virtuous excellence.

The MIDDLE PLAN, which we have already mentioned, seems calculated to blend, in some degree, the advantages, and to divide the disadvantages, of both the others. By enlarging a private school, so as more nearly to approach a public one, you secure every desirable advantage for emulation. And, by having no more, than can be under the continual inspection and management of the master, you provide for that particular and constant attention to every in-

* The saying of Philip upon the birth of his son Alexander, pays a high compliment to the philosopher; but Aristotle himself could not *command* success. His pupil does not seem to have fully answered to his tutor's care.

"Non tam gaudeo, quod natus est mihi filius, quam quod tempore Aristotelis natus est, cui tradatur erudiendus."

dividual,

dividual, which is absolutely necessary to his best improvement.

But upon every plan, the whole will depend upon the ability, the industry, and I may add, particularly, upon the *manner* of the master. The advantages of the best plan may be lost, by incapacity and negligence. And even the worst may have a temporary brilliancy, from the superior talents and attention of him who conducts it.

The noblest authority is that of love, mingled with reverence. Let us imagine, connected with real abilities, that indescribably happy *manner*, which we have already mentioned, but cannot explain. There will probably be an easy and willing empire, over pleased and unsuspicious subjects. It will be an empire over the heart. Their subjection will be chearfully paid to one in whom they see, powers in their eye so amazing, connected with a temper so amiable, with manners so awfully engaging, with affections so sincere, and with a treatment so generous, manly, and consistent.

But, if we recollect a moment the exceedingly difficult points, to which education should be directed, we shall perhaps rather wish, than expect, to see any scheme, in which they may be all accomplished. To keep up the continual impression of reverence, without intimidating—to restrain the spirits, without depressing them—

to inspire courage, without turbulence—vivacity, without forwardness—and diffidence, without dejection—to administer praise, without puffing up—correction, without exasperating—and steady discipline, without enfeebling the mind in its best energies.—These are some of the grand objects of education.

Who, that considers the *difficulties* of this work, the various dispositions, capacities, and nursery-educations of boys; and the different tempers, views, and talents of parents and masters, will not be ready to make every candid allowance for imperfection? And yet, who, that considers ITS INFINITE IMPORTANCE, will not wish every possible imperfection to be done away?

And who will not be ready to exclaim, with the philosopher,

“ Quid munus reipublicæ MAJUS MELIUSVE afferre possumus, quam si docemus atque erudimus Juventutem ? ”

Cicero.

*A PLAN for the IMPROVEMENT and EXTENSION of
LIBERAL EDUCATION in MANCHESTER. By
THOMAS BARNES, D. D. Read April 9, 1783.*

IT is to the honour of the present age, that it has extended the empire of SCIENCE, and of the Arts, so far beyond its antient boundary. The spirit of Literary enterprize has gone forth, and has already won large domains from the regions of darkness. It would be matter of wonder, and of lamentation, if, in a period so distinguished, *education*, which holds so high a rank both as a science, and an art, should not have received some share of the general improvement. But who will deny, that much has been already done, to render the benefits of liberal culture more diffusive, and more successful? Much as we lament, that the object and aim of many parents should be so low; much as we despise many of those frivolous embellishments, which are esteemed the grace and finishing of modern—modish—education, still we must acknowledge with pleasure, that considerable advances have been made, and that young persons now enjoy many assistances in mental cultivation, unknown to their progenitors. The general sentiment,
of

of the influence and moment of superior education, is now almost universally adopted. And nothing, we are confident, is necessary, but to produce a well-conceived and useful scheme, in order to secure the most honourable patronage, and the most liberal encouragement.

There yet remains ONE DESIDERATUM in Education, which many parents would be happy to see supplied, upon an unexceptionable plan. The stage which passes between a SCHOOL, and BUSINESS, is often a very distressing one to a parent, and an useless, if not a dangerous one, to a young man. He has passed through the common forms of Classical Institution. He is rather too old, to continue to pace round the beaten track of a grammar school; and yet he is too young, to be trusted abroad in the world, as his own master. Add to this, that his education, thus far, has been too confined and imperfect, to answer its noblest ends, of giving a true enlargement and direction to his ideas, and of producing a proper taste for general and important science.

What shall be done to fill up this awkward, and yet unspeakably interesting, chasm of life? —It is beyond measure desirable, that it might be filled up with the pursuit of knowledge, in some line, so as to assist and adorn all his future progress.

Every respectable tradesman must have in his view the idea, of sometime retiring from, or at

least of lessening, the multiplicity of cares and attentions which now press upon him. The decline of life seems to call for respite and consolation. But how shall this recess from business be supported, without some taste for letters? I cannot figure to myself a more miserable situation, than that of one, who retires from the hurry of the world, yet has no furniture of mind, to grace or to sweeten his retirement? Unqualified for every liberal and superior entertainment, he will probably sink down, into languor—intoxication—and lethargy.

It is the natural, the laudable wish, of every parent, whom the blessing of Providence has raised to any degree of affluence, that his son may appear in the world, with character and accomplishments, worthy of the respectable line, into which his father's fortune may introduce him. Mere money, without knowledge or virtue, is contemptible and mischievous, in exact proportion to its amount. He must have amusements and companions. But these will be of the lowest, and most degrading cast. His money, however, *he* will deem sufficient to give him self-consequence. With flatterers, with the mob, it *may*. But, destitute of the best possessions, he will be an object of contempt, to all men of sense—and of compassion, to every man of humanity and seriousness.

Without

Without throwing the most distant reflection upon that plan of classical education, which generally, and, in my idea, very properly obtains at our common schools, no one will imagine, that the knowledge there acquired is sufficient to improve and adorn the mind, in all its future stages. Such knowledge must be scanty, and undigested. There will be some shining particles, probably mixed with a large quantity of alloy. Language is merely the scaffolding of science. The shreds and fragments of sentiment, which a boy picks up, in conning over the Latin and Greek authors, are not surely deserving of the name, of regular and systematic science. And yet, without something of system and regularity, ideas float in the head in unformed masses, without method, or arrangement.

The boy, who excels in one branch, the knowledge of languages, may appear manly. The man, who has gained no more, must appear a boy. He that does not add general science to professional knowledge, is a mere pedant. And he who has not looked abroad from the Greek and Roman classics into the other branches of a polished and extensive education, knows but little of what is either most truly ornamental or useful. But WHERE shall that higher and more finished knowledge be obtained?

Here a boy must stop short—When, from names and words, he should rise to THINGS, he

is plunged immediately into the vortex of business—and from that moment, almost the whole of what he had been so many years in learning, is forgotten. At least, little remains, but the withered scraps of knowledge, gleaned in his school. All the science which a boy of an ingenuous turn acquires, AFTER THIS, must be acquired without assistance. He has no preceptor to direct him; he has no regular system to pursue; his walks into the different ranges of literature must be desultory, solitary, and uncomfortable.

For, WHERE shall this knowledge, or this taste be obtained?—In a college, or university?—But there, the expence deters: the danger terrifies. Numbers of young men, many of them irregularly educated, flushed with money, with consequence, with passions, too often corrupt one another, and induce fatal habits of extravagance, dissipation, and indolence—habits, entirely inconsistent with the sobriety, frugality, and attention necessary to future success and reputation, in any line of life—and above all, in BUSINESS.

Hence it is, that so very few of those young men, who are destined for trade, enjoy any advantages beyond those of a grammar school.

It is granted, that the examples are too rare, of those who have united, the manners of the Gentleman, the taste of the Scholar, and the industry

industry of the Tradesman. Yet such examples *have* been seen, and may *still* be seen among us. For who will say, that they are incompatible? or who would not wish that his son might exhibit so fair, so amiable an assemblage of excellence? Perhaps, one reason why they are so uncommon may have been, that those places of education, which tend to form the Gentleman and the Scholar, have been unfriendly to the habits necessary to the Tradesman; whilst the warehouse, in which the Tradesman receives his mercantile mould, is, perhaps, equally unfavourable to superior ornaments. But would it not be possible, that the advantages of both should be combined together? In the house of a parent, or respectable master, and amidst general habits of business, a young man, who should continue to devote some part of his time to study, would not be so much refined, as to be unfit for commerce. And, perhaps, the happy art might be learned, of CONNECTING TOGETHER, LIBERAL SCIENCE and COMMERCIAL INDUSTRY. If the scheme appears visionary, yet it deserves a trial. It is, indeed, as far as I know NEW. I have never heard of a similar establishment. But it might easily be dropped, as soon as it appeared not to answer the ends of its institution.

A plan of this nature, in a large town, it does not appear to me difficult to form, or to execute,

if there were a general conviction of its utility, and a proper encouragement for undertaking it. This course of study should not, I think, be a mere continuation of that of a school; but, the application of school learning to superior objects. Those objects would probably be, *Natural Philosophy*, the *Belles Lettres*, and *Mathematics*; together with some attention to *History*, *Law*, *Commerce*, and *Ethics*. There are Gentlemen in this town, sufficiently eminent in these various departments of science, to lecture upon them with reputation and success. One part of a COLLEGE plan must indeed be dropped—that of living together in common apartments. But, probably, the omission of this would not be deemed a loss, by those, who know the temptations which often attend it. All the advantages of literary improvement might be here enjoyed.

A very important part of the plan would be, A course of lectures upon NATURAL PHILOSOPHY, in its extended sense, which should pay a very particular attention to CHEMISTRY, and MECHANICS, because of their intimate connection with our manufactures.

In addition to these, Courses of lectures upon HISTORY, COMMERCE, JURISPRUDENCE, CRITICISM, and ETHICS, together with the whole range of the BELLES LETTRES might, I persuade myself, be of essential service.

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If with these were combined, some continued attention to LANGUAGES, antient and modern—and to MATHEMATICS—the scheme would be filled up, in a manner highly respectable and useful.

Some establishment of this nature seems wanting, to compleat the many advantages for education, which are already enjoyed among us. Perhaps, few places can boast of greater advantages for the education of boys, in the first rudiments of school learning. Our more public and more private schools have justly obtained a very considerable celebrity, not only at home, but abroad. If, to so fair a foundation could be added a superstructure equally excellent, the whole edifice would appear compleat, strong, and noble.

A scheme like that we are now sketching, might serve as a very agreeable preparation for those, who are designed for the LEARNED PROFESSIONS by opening their way to those more profound and systematical instructions, which they would afterwards receive, in our more public and celebrated institutions. And, to those Gentlemen designed for the COMMERCIAL line, it would be abundantly sufficient, in order to give that general insight into science, which might answer the noblest purposes of mental cultivation.

We have already mentioned, the intermediate stage, between a school and business, as often an

useless, if not a dangerous one for youth. And yet, who would scruple to say, that more depends upon this period, as to the formation of manners, of habit, and of future character, than perhaps upon any other part of life, of equal duration? In this period, from fourteen to seventeen or eighteen years of age, the transition is made from boyishness to manhood. The company, the taste, the plan of future life are now generally established. In this spring, you behold the blossoms; you prognosticate the fruit. A boy, before the age of fourteen, very seldom sees the end towards which he is going. After that age, he begins to observe the point he should aim at: and not unfrequently, he gets more of real knowledge, and of the proper bent and direction of the mind, in two or three years after that period, than in all that have preceded it.

But what shall a young man do, during this important interval? Shall he stay at home? But here, probably, is no object before him, to fix, to entertain, or to improve his mind. He is in danger, therefore, of falling into listlessness, and languor; of flying from this inactivity, so irksome to the sprightliness of youth, into improper and dangerous connections; or of seeking for amusement in gay company, the consequence of which is, dissipation and ruin. Hence, the trembling parent often finds himself obliged to send his son abroad into the world, though ever so desirous

desirous to keep him longer under his own eye, because he is sensible, he is losing time, and in danger of contracting habits of indolence, or of vice.

And even after a young man is engaged in business, there are many long evenings, and many hours of avocation, which might be usefully and agreeably filled up. Shall all the labour of so many years, as have been spent at school, be lost, and buried in everlasting oblivion? Shall so much pains have been taken, in laying a foundation, and in erecting scaffoldings, and shall the mind never rise from thence, to the higher regions of literary improvement? Shall a boy close his school books, and, from that moment, never open them again? Shall he bid farewell to study, and condemn the labour and difficulty, which he underwent in the stage of youth, merely because he has not learned to *apply* the knowledge he there gained, to its noblest end?

It is indeed argued, by some, "That science and business are incompatible; and that a taste for the *one*, almost necessarily disqualifies a man for succeeding in the *other*." But surely a taste for knowledge is not half so detrimental, as that rage for pleasure, which so universally, and almost necessarily prevails, where a better relish has not previously been formed. Would not a taste for manly knowledge be a noble antidote against
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the allurements of corrupting pleasures? Would a young man be in so much danger of being drawn aside into conviviality, or fashionable amusements, if he had a rational and agreeable entertainment at home; if he could retire from his warehouse, and relieve his jaded spirits by some animating study, and thus set a finer edge upon his mind again, blunted and worn down by intense application?

It is plain, that many of our tradesmen, the most industrious and successful, have many hours of avocation. Human nature could not endure a perpetual screw to business, without relaxation. Might not these hours be often filled up much better, more honourably more usefully, more happily, than they commonly are? Would mental cultivation, to a certain point, interfere with the necessary demands of business? I know, it is generally thought so. But it is true in fact? Shall we be told, "That most of our eminent tradesmen rose from low beginnings by unremitting industry, whilst those, who set out with fairer fortune and prospects, made comparatively little progress?" But is not the reason of this, that our young men, instead of forming a manly and cultivated taste, fell into company and habits, which effectually dissipated their minds, and unfitted them for proper attention to any important object whatever?

But,

But, "There have been young men too bookish for a warehouse"—It is granted. But it is probable, they never had a proper turn of mind for business. Their parts were wrong cast. They should have been brought up to some liberal profession, more agreeable to their genius. They were probably obliged to enter upon a line of life not correspondent to their ruling passion. No wonder, they did not succeed!

The object to be aimed at is, To give a boy, in these intermediate years, to which alone our plan extends, that degree of knowledge and of taste, which may make him more than the MERE MAN OF BUSINESS in future life. The point to be avoided is, The giving him views, habits, and taste, which may be UNSUITABLE FOR A MAN OF BUSINESS, and which he would have to unlearn again, when he came to settle down to the regular *routine* of a warehouse.

How far it would be possible to gain this advantage, and to avoid this disadvantage, is a point of the utmost concern to determine. Might not a boy, for some years after he has been introduced into business, have some intervals allowed him, which might be sufficient for the cultivation of his mind? Is it necessary that, the moment he enters a warehouse, he should lay down this maxim—"I must now give every moment to trade—I must have but ONE object

object—I must give up books, knowledge—and every thought but ONE, that of getting money?”

And even admitting, that there were some competition, such as is asserted, between literature and merchandize; if the plan we are recommending should in any degree interfere with an unremitting and excessive attachment to business—is it necessary that business shall be followed upon this slavish and degrading plan, to the exclusion of every idea, but that of gain? Might not something be abated of this overplodding diligence, and yet the mind, even granting some diminution of fortune, be, upon the whole, an unspeakable gainer?

It would certainly be a high honour, as well as an unspeakable advantage, to this rising and opulent town, to have within itself an Institution which would proclaim its taste, as well as its affluence. It would be a laudable ambition, to aspire after a literary, in addition to that mercantile reputation, by which it is already so greatly distinguished.

The SOCIETY to which I have now the honour of addressing myself, has added no small degree of respectability, in the eyes of our fellow-countrymen, and even of foreigners. They have seen, with pleasure, a set of Gentlemen rise up, in the midst of a place devoted to commerce as the friends of LITERARY and PHILOSOPHIC excellence. An institution, such as I am now recommending, would strengthen that favourable impression,

impression, by declaring to the world, that increasing wealth is accompanied with its rare, but honourable attendant, increasing wisdom—and, that those, whose sagacity and industry have been able to extend the manufactures, are equally desirous of extending the best improvement and embellishment, of their country. It would contradict the disgraceful idea, that a spirit of merchandize is incompatible with liberal sentiment, and that it only tends to contract and vulgarise the mind.

But, Gentlemen, in order to the success of this plan, it is necessary, that it come before the public UNDER YOUR PATRONAGE AND PROTECTION.—That these imperfect outlines be improved and filled up by your maturest deliberations—That different Gentlemen shall engage in different departments—And that the scheme be prosecuted with vigour, with harmony, and with perseverance.

Under such a sanction, and with such advantages, it could not fail of success. Perhaps it might become, in the course of years, like a rill, swelled in its progress by successive tributary streams, a noble torrent, and enrich, and adorn the country all around,

N. B. *The Scheme here recommended being approved, and patronised by the SOCIETY, the following Paper was, at their desire, drawn up by the Rev. Dr. BARNES, and circulated, with the annexed testimonial from the PRÉSIDENTS.*

RESOLVED,

MANCHESTER, APRIL 23, 1783.

RESOLVED, *at a Meeting of the LITERARY and PHILOSOPHICAL SOCIETY—That the following Paper, drawn up by a Member, at the Request of the Society, be printed, and offered to the Consideration of the Public.*

JAMES MASSEY,
THOMAS PERCIVAL, } PRESIDENTS

PROPOSALS *for* ESTABLISHING *in* MANCHESTER
a PLAN of LIBERAL EDUCATION, *for* YOUNG
MEN *designed for* CIVIL and ACTIVE LIFE,
whether in TRADE, *or in any of the* PROFESSIONS.

THERE is no subject, except RELIGION, in which every person is more deeply interested, both as an individual, and as a member of society, than in EDUCATION. And it is to the honour of the present age, that it encourages, with distinguished generosity, every well-planned scheme, the object of which is, to improve the system of education, and to extend its beneficial influences.

In few places has this liberal spirit appeared, of late, more conspicuously, than in MANCHESTER. There are, indeed, few places, which have enjoyed

enjoyed the advantages of *early tuition*, in a more eminent degree. Our *public* and *private* schools have justly obtained a very considerable celebrity, both at home and abroad.

There is, however, in the opinion of many intelligent persons, deeply interested in the subject, something essential still wanting among us, to compleat the course of education, for active and commercial life. In their judgment, a period subsists, in the life of a young man designed for trade, which it is not easy to fill up in the most advantageous manner. The want of a happy transition from a grammar school to business, by some mode of more general and manly instruction, suited to that intermediate stage, has been sensibly felt, as a *desideratum* of unspeakable importance. At present, there is hardly any *middle line* of education, between that, of a school for the elements of language and accompts, and that, of a college—the latter of which seems better adapted for a professional man, than for one designed for commerce. It is surely desirable, that he shall *now* rise, from words to things, from Language to sentiment. All that he has yet been doing, is only preparatory to real knowledge. Language, of itself, is but a scaffolding to science. And shall the labour of so many years be now lost and forgotten, as it too commonly is, when a young man leaves the school, and enters upon life? Or, shall the gleanings of mixed
and

and casual sentiment, collected from a few *Greek* or *Roman Classics*, constitute all the knowledge, which is to adorn and sweeten the remainder of his days? Might not, then, this period be filled up with great advantage, in the acquisition of SUPERIOR SCIENCE, if there were the opportunity at hand, of some well-digested and unexceptionable plan?

Probably, in these intermediate years, the taste, the habits, and the whole character of a youth, may receive indelible impressions. From *these years* we are to date, his honour, his insignificance, or his infamy—his success, or his ruin. Of what infinite importance is it, then, that this interesting period be cultivated with the utmost diligence, and sown with every seed, capable of producing real happiness or ornament, in future life!

But there are some, who deny, that any such intermediate stage, as we have here supposed, *does*, that is, *ought to exist*. They contend, that a boy should be set down, *as soon as possible*, to active and constant business, in order to obtain, by early initiation, all the habits of industry and attention, necessary to future success.—Such Gentlemen will not surely say, That what a youth has acquired at fourteen years of age, supposing him to have made ever so great a proficiency in school learning, is sufficient to constitute the whole of his mental furniture hereafter!—Or, that

that any higher degrees of liberal science are incompatible with business! A severer libel upon trade could not possibly be uttered! If it were *true*, who would not wish to abate a little of the qualifications of the mere tradesman, in order to enjoy the more respectable ornaments, of knowledge, and mental cultivation?—But there are many examples in MANCHESTER—and we point to them with pride and pleasure,—of the union of a taste for literature, with every necessary and desirable requisite for active and successful commerce. Who does not wish to see the number of *such characters* multiplied among us? Who would not rejoice, *thus* to confute that degrading maxim, that commerce only serves to enfeeble and contract the noblest powers of the human mind *

But,

* In the Memoirs of Albert de Haller, M. D. lately published by Mr. Henry, we are told, page 119, “That he laid a plan for a school, designed for the education of the opulent citizens; where they might be qualified to fill the principal offices of the republic, and might be instructed, not so much in those points, which the grammarians of the seventeenth century esteemed the most essential branches of education, as in those, which the philosophers and men of learning of the present age have judged to be essential to the interests of humanity.”—This was at BERNE, a place supported by arts, manufactures, and commerce.

In the instructions lately issued from the Lord Lieutenant of Ireland, to the Earl of Tyrone, &c. to consult
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But, let us imagine a young man, engaging in business, at fourteen or fifteen years of age: There must occur, for a few years at least, many hours of relaxation, which might be usefully and agreeably employed. If the duties of the warehouse employ the *day*, a part of the long winter *evenings* might be spent, in a more rational and improving manner, than they too commonly *are*—than they necessarily *must be*, if there be

upon a plan for accommodating the GENEVANS, who are coming to settle in Ireland, is the following paragraph: “ And whereas young persons of rank and fortune, from all parts of Europe, resorted to the city of Geneva, to profit from the system of education established there, under professors of eminence in useful and liberal studies and accomplishments; and whereas a School or Academy formed upon the same principles in this kingdom, would forward his Majesty’s gracious dispositions for the encouragement of religion, virtue, and science, by improving the education and early habits of youth, and would remove the inducements to a foreign education; and, being conducted with that attention to morality and virtue, which hath distinguished the establishments in that city, may attract foreigners to reside in this kingdom for the like purpose: we do further pray and empower you, to consider and digest a plan for a School and Academy of education, to be established in the new colony, and to make a part of the constitution thereof, under such institutions and regulations, and with such privileges, as may best contribute to the ends hereby proposed.”—At GENEVA, arts and manufactures flourish in the highest degree, befriended and assisted by the SCIENCES.

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not some taste for literary entertainment. Amusement is necessary to young men. If this be not enjoyed *at home*, and *within themselves*, they will fly abroad into company, and seek it, in taverns, in conviviality, and dissipation. Hence, they will form habits, of all others the most unfavourable to success in business, and against which, a relish for manly science would have been, next to religion, the noblest antidote. Let the list of bankrupts be examined—For *one*, who has fallen, a sacrifice to literature and refinement, it would be easy to point out *a hundred*, who have fallen, for want of that rational, domestic, and delightful entertainment, which a proper taste for knowledge would have afforded them.

Few young men are admitted to *manage* a business, till they are, at least, eighteen years of age. Before this age, they would not, probably, have prudence or steadiness, to deserve so great a confidence! Till *then*, their intervals of leisure give them a perfect remission from care. The improvement of their minds, in these intervals, if not carried beyond a certain point, would not interfere with mercantile accomplishments. It would afford a grateful recess, from the bustle and attention of business. It would hereafter give a man the *habit*, and the *means*, of filling up whatever leisure he may command, in a most agreeable manner. It would give him

respectability and consequence, even upon the exchange. And it would cheer his retirement, if, in the evening of life, he should wish to decline, or diminish, the multiplicity of cares, which now press upon him.

But *where*, in the present state of things among us, shall this mental cultivation be obtained? We have no regular established means, for such an acquisition. There are some young men, surely not the least respectable among us, who are, with a laudable ambition, endeavouring to glean such instruction, by their own solitary and desultory efforts. For want of proper assistance, their progress is necessarily slow, embarrassed and uncomfortable. They lose much valuable time. And, after all, the knowledge they *do* acquire, wants much of that precision and arrangement, which can, in general, only be attained by regular and systematic study.

It is therefore proposed, to ESTABLISH in MANCHESTER, a SEMINARY of LIBERAL SCIENCE, the object of which shall be, to give a young man some taste for SUPERIOR KNOWLEDGE, to provide him with a domestic, constant, internal source of entertainment, and thus to improve his morals, his piety, and his happiness—at the same time, that he is forming early habits of commercial industry. The design of this plan is, to connect the one of these, with the other—the

the improvement of the *mind*, with the proper attentions to *business*. This union, of mercantile and mental accomplishments, is certainly of unspeakable importance to those, whose fortunes and prospects destine them to move in the higher spheres of life. The respectable and superior tradesman may be allowed to have his mind well furnished, and his sensibilities refined, without injury—nay, with very great advantage, even to his trade itself. By means of superior education, he will be enabled to appear in the world, in that line, to which an honourable ambition should prompt him to aspire. His connections will be more advantageous. To his customers, to his friends, to his fellow-citizens, to foreigners, to the world in general, he will appear with greater consequence and respectability. His advice, his example, his influence, will have a weight, which *mere fortune*, without mental cultivation, can never, of itself, command.

It is further proposed, That several Gentlemen shall unite together, in delivering a course of liberal instruction, in LANGUAGES, the BELLES LETTRES, HISTORY, COMMERCE, LAW, ETHICS, NATURAL PHILOSOPHY, CHEMISTRY, and MATHEMATICS.

In this institution, every narrow principle ought to be rejected. A plan, formed for public utility, should be generous and enlarged, so

as to extend itself as widely as possible, for the common interest. Science and Arts are of no political or religious party. They tend, in the happiest manner, to destroy those little prejudices, which alienate one man from another. By opening the soul to wider aims, they improve our charity, our morals, our christianity—and, by necessary consequence, exalt our truest happiness.

At present, we can only sketch a *rude* and *general outline* of the scheme now in contemplation.

The LEARNED LANGUAGES form so important a part of LIBERAL EDUCATION, that it is not necessary to enlarge on the propriety of continuing and increasing an acquaintance with them. This it is proposed to do, by lectures, upon a popular and entertaining plan, which shall connect occasional remarks, on the history, mythology, philosophy, manners, jurisprudence, &c. of antient times, with the authors which shall be read.

The BELLES LETTRES present a wide field for highly interesting and useful lectures upon *Criticism*, *Poetry*, *Oratory*, and the *Polite Arts*. To this department may likewise be added, lectures upon GENERAL HISTORY, and particularly, upon the HISTORY of our own COUNTRY—upon COMMERCE—LAW—LOGIC—and MORALS. These various subjects open so many views into human nature, as cannot fail of delighting the mind,
and

and improving it in its best principles and operations.

NATURAL PHILOSOPHY in all its branches, (except Chemistry)—including *Optics, Pneumatics, Hydrostatics, Astronomy, Electricity, &c.*—or the discoveries relating to *Vision, Air, Water, the Heavenly Bodies, Electric Fire, &c.*—and attended with experiments, on *Microscopes, Telescopes, Air-Pumps, Fire-Engines, Orreries, Electric Machines, &c.* will form a very large and important part of the proposed plan.

CHEMISTRY will be a province by itself. Its extent, and reference to so many of the *arts*, on which our *manufactures* depend, entitle it to this distinction. Here, will be considered, the elementary principles of *bodies*, the nature of *Fire, Air, Acids, &c.* And the whole will have a reference to the *arts* of *Dyeing, Bleaching, &c.* which, depending upon chemical principles, might probably, by the knowledge of those principles, be very greatly extended and improved.

The MATHEMATICS, including *Geometry, Trigonometry, Conic Sections, Algebra, &c.* would sufficiently fill another department, of the importance of which no detail is here necessary.

A SCHEME, THUS FILLED UP, would, we flatter ourselves, comprize the principal objects, most desirable in a SEMINARY OF LIBERAL INSTRUCTION. If, however, it should be found proper to add to these, *other* branches of science, such

AS NATURAL HISTORY, MODERN LANGUAGES, &c. &c. it is not doubted, but that Gentlemen, well qualified to lecture upon them, would concur in giving assistance and perfection to a plan of such general utility and importance.

If, to provide a preservative from those low, corrupting pleasures, by which thousands of our young men are continually destroyed—If, to extend still further the branches of our commerce, the sinews of our wealth, by disseminating those principles, on which the arts depend—If, to prepare an agreeable entertainment for every period of life, and an honourable character and consolation for its evening—If, to add respectability to opulence, and dignity to human nature—If THESE are objects, worthy our first regard, the Institution here proposed, appears to wear an aspect, friendly to human excellence and human happiness, and to deserve the patronage of our fellow-citizens. The more it is considered, the more, we trust, it will appear to merit their approbation and encouragement.

We have mentioned it, as *principally* accommodated to young men, designed for a respectable line of *trade*. But those, who are designed for the different *professions*, as well as those, who have *no* particular profession in view, will, probably, find very considerable advantage from it, either, as preparatory to the university, or to life in general. And there are many Gentlemen, further advanced in age, who have sufficient

cient leisure and disposition for such pursuits, to whom it would, possibly, be an agreeable circumstance, to have the opportunity of spending two or three hours in a week, in so rational, and improving an entertainment.

Strongly impressed with these ideas, the Gentlemen who wish well to this scheme, hope to see it prosecuted with zeal and perseverance. They conceive, that it will be an honour to the town of MANCHESTER, to have within itself such an institution, as that here proposed, and to take the lead, among the other great towns of this opulent kingdom, in establishing a plan, which, it is not improbable, many others will be ambitious to follow.

If, upon this *general view*, THIS INSTITUTION should appear worthy of the attention and patronage of the PUBLIC, a more *particular* account of its *extent* and *objects* will be given, in another paper,—together with a distinct syllabus of the lectures proposed to be delivered, in every separate department. And, it is hoped, that its commencement may take place the ensuing winter.

N. B. It is proposed, that the lectures shall be delivered in the EVENING, or, so as not to interfere with the regular hours of business.

It may not be improper to mention, that the scheme here proposed has been carried into execution with considerable success. During the two last winters, LECTURES have been delivered, IN DIFFERENT BRANCHES OF SCIENCE, to numbers of Gentlemen, who have thus given the most respectable sanction to the undertaking. And it may be added, that the Gentlemen engaged in the office of PRÆLECTORS, animated with the encouragement they have already received, hope to pursue their important object with vigour and perseverance, not doubting but that they shall continue to enjoy the patronage and support of the friends of science and of virtue.

As it is desirable that SIMILAR ESTABLISHMENTS should be formed in OTHER LARGE TOWNS, it will not probably be amiss to subjoin the FIRST REPORT of this institution, printed 1783.

COLLEGE OF ARTS AND SCIENCES,

INSTITUTED AT MANCHESTER, JUNE 6, 1783.

THIS INSTITUTION is intended to provide a course of LIBERAL INSTRUCTION, compatible with the engagements of commercial life, favourable to all its higher interests, and, at the same time, preparatory to the systematic studies of the UNIVERSITY. To unite *philosophy* with *art*, the moral and intellectual culture of the *mind*, with the pursuits of *fortune*, and to superadd the noblest powers of enjoyment to the acquisition of wealth, are the great objects which it professes to hold in view. The consistency of these objects has been fully ascertained; and their importance cannot be doubted. It only remains, therefore,

to state the particulars of the plan, which now claims the attention, and the support of the public. And the GOVERNORS of the COLLEGE indulge the pleasing, patriotic hope, that the following CONSTITUTIONS and REGULATIONS will ensure to their undertaking, permanency, respectability, and success.

CONSTITUTIONS.

I. That the Lord LIEUTENANT of the County Palatine of LANCASTER, and the KNIGHTS of the SHIRE, be appointed PATRONS of the college, and requested to honour the institution with the sanction of their names and authority.

II. That a PRESIDENT, and EIGHT GOVERNORS be appointed, who, together with FOUR of the senior, or first nominated PRÆLECTORS, (not being GOVERNORS,) shall jointly transact all the business, and direct all the affairs of the institution,

III. That the PRESIDENT, GOVERNORS, and PRÆLECTORS, shall hold their respective offices, *quamdiu se bene gesserint*; and shall not be removeable, but by the votes of *two thirds* of the whole presiding body.

IV. That the number of GOVERNORS shall not, hereafter, be changed, nor any election made, but to fill up the vacancies, which may at any time happen; and that such election shall be made within *three months* after the vacancy.

V. As a mark of respect to the LITERARY AND PHILOSOPHICAL SOCIETY of MANCHESTER, which has so fully discussed the merits, and so zealously encouraged the plan of this institution, that the present nine officers, viz. the PRESIDENTS, VICE-PRESIDENTS, SECRETARIES, and TREASURER, be appointed GOVERNORS of the college.

VI. That

VI. That *two meetings* of the *officers* and *prælectors*, of the college, shall be held *annually*, viz. on the last *Thursdays* in the months of *September* and *March*.

VII. That the *PRESIDENT*, or any three *GOVERNORS*, be impowered to call a meeting of the *OFFICERS* and *PRÆLECTORS*, whenever, *he*, or *they*, shall judge it expedient or necessary.

REGULATIONS.

I. That all decisions of the *GOVERNORS* and *PRÆLECTORS*, if required, shall be by *ballot*: and, that a number less than *seven*, to be convened by a general summons, shall not be competent to transact business.

II. That *Tuesday*, *Thursday*, *Friday*, and *Saturday*, be the *days* appointed for the lectures, in the ensuing session: and that the *time* of lecturing be from about *six* to about *nine* o'clock in the *evening*, with the intermission of about half an hour, or an hour.

III. That a lecture shall not, usually, exceed *an hour*: and that no more than *two lectures* shall be delivered in the course of *one evening*.

IV. That it be recommended, that no more than *two lectures* be given by each *PRÆLECTOR*, *weekly*.

V. That the *FEES* to be paid shall not exceed *two GUINEAS* per session, to each *PRÆLECTOR*, whose course is attended; and that no alteration shall be made in these terms, without the consent of a majority of the *GOVERNORS* and *PRÆLECTORS*.

VI. That the subsequent season of lecturing shall commence about the beginning of *October*, and end about the beginning of *April*.

VII. That no *free tickets* of admission shall be given: but that the lectures shall be open to all the *OFFICERS* and *PRÆLECTORS* of the *COLLEGE*.

LECTURES

LECTURES to be delivered the ensuing Session.

I. On PRACTICAL MATHEMATICS—the principal branches of NATURAL and EXPERIMENTAL PHILOSOPHY—GEOGRAPHY—and the use of the GLOBES; by Mr. HENRY CLARKE (*This course was not delivered.*)

II. On CHEMISTRY, with a reference to ARTS and MANUFACTURES; by Mr. THOMAS HENRY, F.R.S.

III. On the THEORY and HISTORY of the FINE ARTS; by Mr. GEORGE BEW.

IV. On the *origin, history, and progress* of ARTS, MANUFACTURES, and commerce,—the COMMERCIAL LAWS and REGULATIONS of different COUNTRIES,—the nature of COMMUTATIVE JUSTICE; of OATHS, CONTRACTS, and other branches of COMMERCIAL ETHICS; by the Rev. THOMAS BARNES.

V. *A course of lectures on MORAL PHILOSOPHY was delivered, BY THE SAME, in 1784.*

OFFICERS OF THE COLLEGE.

P A T R O N S.

The Right Honourable the Earl of DERBY:
Lord Lieutenant, and Custos Rotulorum, of the County Palatine
of LANCASTER.

Sir THOMAS EGERTON, Bart. }
TOMAS STANLEY, Esq. } Knights of the Shire.

P R E S I D E N T.

THOMAS PERCIVAL, M.D.F.R.S. & S. A. &c. &c.

G O V E R N O R S.

James Massey, Esq.	Charles White, Esq. F.R.S.
Rev. Thomas Barnes.	Mr. Thomas Henry, F.R.S.
Alexander Eason, M. D.	Mr. George Bew.
Rev. Samuel Hall, A. M.	Mr. Isaac Mosse.

The

THE PRESIDENT and GOVERNORS of this COLLEGE are authorized to inform the public, that, whenever it may be deemed expedient to *extend* the plan, so as to render it a proper introduction to PROFESSIONAL STUDIES, in the UNIVERSITIES, Gentlemen of distinguished merit, in *different departments* of science, have promised to unite their labours, with those of the PRÆLECTORS, who now engage in the undertaking. And they flatter themselves, that, as this institution disclaims all relation to *parties*, either in *religion* or *politics*, and originates in the most generous and laudable views, it cannot fail to meet with candour, approbation, and encouragement. Many honourable testimonies, in its favour, have already been received, from the ablest judges. And the GOVERNORS acknowledge, with peculiar satisfaction, the very obliging terms in which the Lord LIEUTENANT of the COUNTY, and the two KNIGHTS of the SHIRE, have been pleased to sanction it with their patronage. “I shall be happy,” says his Lordship, in a letter to the PRESIDENT, on this occasion, “by every means in my power, to promote an undertaking, carried on upon such liberal principles, and directed to such a noble and beneficial object.”

N. B. Those, who wish to subscribe to any course, or courses of lectures, are desired to deliver their names, *as soon as convenient*, to the president, or to some governor or prælector of the college.

MANCHESTER, July 9, 1783.

On ORICHALCUM. *By the Right Rev. RICHARD WATSON, D. D. F. R. S. &c. &c. Lord Bishop of LANDAFF. Communicated by Dr. Percival. Read October 1, 1783.*

WE have a proof, from the writings of Cicero, that the Romans, in his time, understood by the term *Orichalcum*, a metallic substance resembling gold in colour, but very inferior to it in value. He puts the following case—"Whether, if a person should offer a piece of gold to sale, thinking that he was only disposing of a piece of *Orichalcum*, an honest man ought to inform him that it was really gold, or might fairly buy for a penny what was worth a thousand times as much."* It is not contended, that the argument, in this place, required any great accuracy in ascertaining the relative values of gold and *Orichalcum*; yet we may reasonably conclude from it, that orichalcum might by an ignorant person be mistaken for gold, and, that it was but of small estimation when compared with it.

Julius Cæsar robbed the Capitol of three thousand pound weight of gold, and substituted as

* Cicero. de Off. L. III.

much gilded copper in its stead ; * in this species of sacrilege, he was followed by *Vitellius*, who despoiled the temples of their gifts and ornaments, replacing the gold and silver by tin and Orichalcum. † From this circumstance also, we may collect, that the Roman Orichalcum resembled gold in colour, though it was far inferior to it in value.

It is probable, that the Orichalcum here spoken of was a metallic substance, greatly analogous to our brass, if not wholly the same with it. The value of our brass, is much less than that of gold, and the resemblance of brass to gold in colour, is obvious at first sight. Both brass and gold, indeed, are susceptible of a variety of shades of yellow ; and, if very pale brass be compared with gold, mixed with much copper, such as the foreign goldsmiths, especially, use in their toys, a disparity may be seen ; but the nearness of the resemblance is sufficiently ascertained in general, from observing that substances gilded with brass, or, as it is commonly called, Dutch leaf, are not easily distinguished from such as are gilded with, gold leaf.

The *Romans* were not only in possession of a metallic substance, called by them Orichalcum, and resembling gold in colour, but they knew

* Suet. in Jul. Cæs. C. LIV.

† Id. in Vitel. C. VI.

also the manner of making it, and the materials from which they made it, were the very same from which we make brass. I am sensible, that in advancing this opinion, I differ from authors of great credit, who esteem the art of making brass to be wholly a modern invention. Thus M. *Cronstadt* does not think it just to conclude from old coins and other antiquities, that it is evidently proved, that the making of brass was known in the most ancient times;* and the authors of the French *Encyclopedie* assure us, that our brass is a very recent invention. †

Pliny, speaking of some copper which had been discovered near *Corduba* in the province of *Andalusia* in *Spain*, says, “this of all the kinds of copper, the *Livian* excepted, absorbs most *cadmia*, and imitates the goodness of *Aurichalcum*.” ‡ The expression, ‘absorbs most *cadmia*,’ seems to indicate, that the copper was increased in bulk, or in weight, or in both, by means of the *cadmia*. Now it is well known, that any definite quantity of copper is greatly increased, both in bulk and in weight, when it is made into brass by being

* *Miner.* p. 218.

† *Art. Orichalque*—“The vessels here called brazen, after ancient authors, cannot have been of the materials our present brass is composed of, the art of making it is a modern discovery.” See *Laughton’s Hist. of Ancient Egypt.* p. 58.

‡ *Hist. Nat. L. XXXIV. S. 2.*

fluxed in conjunction with *calamine*. The other attribute of the copper when mixed with *cadmia*, was, its resembling *Aurichalcum*. We have seen from *Cicero*, that the term *Orichalcum* was applied to a substance far less valuable than gold, but similar to it in colour; and it is likely enough, that the *Romans* commonly called the mixture of copper and *cadmia* *Orichalcum*, though *Pliny* says, that it only resembled it; he, as a naturalist, speaking with precision, and distinguishing the real *Orichalcum*, which in his time, he says, was no where produced, from the factitious one, which, from its resemblance to it, had usurped its name.

Sextus Pompeius Festus abridged a work of *Verrius Flaccus*, a grammarian of considerable note in the time of *Augustus*. In this abridgement, he defines *cadmia*, to be an earth which is thrown upon copper, in order to change it into *Orichalcum*.* The age in which *Festus* flourished is not ascertained: he was unquestionably posterior to *Martial*, and some have thought that he lived under the Christian Emperors. But leaving that point to be settled by the critics, if he expressed himself in the words of the author, whose work he abridged, we have from him a decisive proof, that *cadmia* was considered as a species of earth,

* *Cadmia-Terra quæ in æs conjicitur, ut fiat Orichalcum.*
Fest. de Ver. Seq.

and that the Romans used it for the converting of copper into a metallic substance, called, in the Augustan age, Orichalcum.

In opposition to this, it ought to be remarked, that some understand by the *cadmia* of *Pliny*, not calamine, but native arsenic. They seem to have been led into this opinion, from observing that *Pliny* says, *lapis ærosus* was called *cadmia*. For, apprehending that by *lapis ærosus* *Pliny* understood a kind of stone which caused ulcers and erosions in the flesh of those who were occupied in working it, and knowing that arsenic produced such an effect, they have concluded that *cadmia* was native arsenic.* This, probably, is a mistake, arising from a misinterpretation of the word, *ærosus*. *Pliny* usually, if not constantly, applies that word to substances in which copper is contained, without having any respect to the actions of such substances on the flesh of animals. Arsenic, moreover, when mixed with copper, does not give a gold, but a silver-like appearance to copper. And lastly, *Pliny* in another place expressly says, that the stone from which brass was made was called *cadmia*; now it is impossible to make either brass or copper from arsenic.

* - - - nous soupçonnons que *Pline* a voulu désigner par *Lapis ærosus*, une pierre qui mange et fait de ulcères ou érosions à ceux qui la travaillent, et qui est probablement l'arsenic vierge. *Miner.* par M. Vaimont de Bomare, V. II. p. 64.

Ambrose, bishop of *Milan* in the fourth century says, that copper, mixed with certain drugs, was kept fluxed in the furnace till it acquired the colour of gold, and that it was then called *Aurichalcum*. * *Primasius*, bishop of *Adrumetum* in *Africa*, in the sixth century, observes, that *Aurichalcum* was made from copper, brought to a golden colour by a long continued heat, and the admixture of a drug. † *Isidoras*, bishop of *Seville* in *Spain*, in the seventh century, describes *Aurichalcum* as possessing the splendour of gold, and the hardness of copper, and he uses the very words of *Primasius* respecting the manner of its being made. ‡ The drug spoken of by these three bishops was probably *cadmia*. Prepared *cadmia* is highly commended by *Pliny* as useful in disorders of the eyes, || and it is still with us, under the more common appellation of *calamine*, in some repute for the same purpose. Hence, considering the testimonies of *Festus* and *Pliny* to the application of *cadmia* in making

* *Æs namq; in founace, quibusdam medicaminibus admixtis, tamdiu conflatur, usq: dum colorem auri accipiat, et dicitur aurichalcum.* Amb. in Apoc. C. I.

† *Aurichalcum ex ære fit, cum igne multo; et medicamine adhibito, perducitur ad aureum colorem.*

Prima. in Apo. C. I.

‡ *Aurichalcum dictum, quod et splendorem auri, et duritiam æris possideat, fit autem ex ære et igne multo, ac medicaminibus perducitur ad aureum colorem.* Ind. Orig.

|| Hist. Nat. L. XXXIV. C. 10.

either

either Orichalcum, or a substance imitating the goodness of Orichalcum, we cannot have much doubt in supposing, that *cadmia* was the drug alluded to by *Ambrose*, and of those who seem to have borrowed, with some inaccuracy of expression, his description of the manner of making Orichalcum.

What we call brass was anciently in the French language called *archal*, and brass wire is still not unfrequently denominated *fil d'archal*. Now if we can infer, from the analogy of languages, that *archal* is a corruption of *aurichalcum*, we may reasonably conjecture, that our brass, which is the same with the French *archal*, is the same also with the Roman *aurichalcum*:

Though we may, from what has been advanced, conclude, without much apprehension of error, that the Romans knew the method of making brass, by melting together calamine and copper; yet the invention was probably derived to them from some other country.

We meet with two passages, one in *Aristotle*, the other in *Strabo*, from which we may collect, that brass was made in *Asia*, much after the same manner, in which it appears to have been made at Rome.

Strabo informs us, that in the environs of *Andera*, a city of *Phrygia*, a wonderful kind of stone was met with, which being calcined became iron, and being then fluxed with a

certain earth, dropped out a silver-looking metal, which, being mixed with copper, formed a composition, which some called Orichalcum.* It is not improbable, I think, that this stone resembled *black jack*, or some other ore of zinc. *Black jack* may, in a common way of speaking, be called a stone. It abounds in iron; and, when calcined, looks like an iron earth: it yields zinc by distillation, sometimes mixed with silver and lead; and both the metallic substance which may be extracted from *black jack*, and, the sublimate which arises from it whilst it is smelted, will, when mixed with copper, make brass.

The *Mossynæci* inhabited a country not far from the *Euxine* Sea, and their copper, according to *Aristotle*, was said to have become splendid and white, not from the addition of tin, but from its being mixed and cemented with an earth found in that country.† This cementing copper with an earth, is what is done, when brass is made, by cementing copper with calamine, which is often called, and, indeed, has the external appearance of, an earth: and that Asia was celebrated for its cadmia or calamine, we have the testimony of *Pliny*.‡ The copper of the *Mossynæci* is said to have become *white* by

* *Stra. Geo. L. XIII.*

† *Arif. de Mirab. Op. Tom II. p. 721.*

‡ *Hist. Nat. L. XXXIV. C. 2.*

this operation. Whiteness appertains to brass either absolutely, or relatively: for brass is not only much whiter than copper, but when it is made with a certain quantity of a certain sort of calamine, for there are very various sorts of it, its ordinary yellow colour is changed into a white. Cicero, we have seen, supposes that Orichalcum might have been mistaken for gold, and as such, it must have been yellow; yet Virgil applies the epithet white to Orichalcum,

*Ipse dehinc auro squalentum alboque orichalco
Circumdat loricam humeris.**

Aristotle also speaks of having heard of an *Indian* copper, which was shining, and pure, and free from rust, and not distinguishable in colour from gold;† and he informs us, that amongst the vessels of *Darius* there were some of which, but for the peculiarity of their *smell* it would have been impossible to say, whether they were made of gold or copper. This account seems very descriptive of common brass, which may be made to resemble gold perfectly in colour, but which, upon being handled, always emits a strong and peculiar *smell*, not observable either in gold or gilded copper.

* Vir. *Æn.* L. XII. 87.

† *Arif. de Mirab.* T. II, p. 719.

The kings of *Persia*, who preceded the *Darius* mentioned by *Aristotle*, were in possession of similar vessels; but they seem to have been rare, and, of course, were held in high estimation. Among the magnificent presents of gold and silver vessels, which *Artaxerxes* and his counsellors gave to *Ezra*, for the service of the temple at *Jerusalem*, there were twenty basons of gold, and but two vessels of yellow shining copper, precious as gold, or, as some render the words, resembling gold.* “Sir John Chardin, in his MS. note, has mentioned a mixt metal used in the east, and highly esteemed there; and, as the origin of this composition is unknown, it might, for aught we know, be as old as the time of *Ezra*, and be brought from those more remote countries into *Persia*, where these two basons were given to be conveyed to *Jerusalem*. I have heard, says the note, some Dutch Gentlemen speak of a metal in the island of *Sumatra*, and among the *Macassars*, much more esteemed than gold, which royal personages alone might wear. It is a mixture, if I remember right, of gold and steel, or of copper and steel. He afterwards added to this note (for the colour of the ink differs) *Calmbac* is this metal composed of gold and copper. It in colour nearly resembles the pale carnation rose, has a very fine grain, the polish extremely lively. I have seen some-

* *Ezra*, viii. 27.

thing of it, &c. Gold is not of so lively and brilliant a colour; I believe, there is steel mixed with the gold and copper. He seems to be in doubt about the composition, but very positive as to its beauty and high estimation.”*

The supposition of brass having been anciently made in India, seems to be rendered improbable by both *Pliny* and *Strabo*; *Pliny* expressly saying, that the Indians had no copper, † and without copper we are certain that brass cannot be made; and *Strabo* representing them as so ignorant of the art of fluxing metals, ‡ that, according to him, if they had been possessed of the materials, they would not have had the ability to use them for the composing of brass. But these writers, it is apprehended, knew very little of India. *Strabo*, in particular, laments his want of materials to compose a consistent account of India; and few of the authors, from whose works *Pliny* compiled his natural history, can be supposed to have had any intercourse with that country. *Strabo*, moreover, contradicts both *Pliny*’s observation, and his own. In describing the great pomp with which some of the Indians were accustomed to celebrate their festivals, he speaks of huge gilt kettles, cups, and tables

* Harmer’s Obs. on Scrip. Vol. II. p. 491.

† Hist. Nat. L. XXXIV. C. 17.

‡ Geo. L. XIV.

The Bishop of Landaff on Orichalcum.

made of *Indian* copper ; * from which it appears, not only that the Indians were not destitute of copper, but that they were skilful metallurgists, since they knew how to flux it, to form it into vessels of various kinds, and to gild it. Perhaps, this Indian copper, of which the vessels were made, instead of being gilt, only resembled gold in colour, and was really a sort of brass. It is granted that this is but a conjecture, but it is not devoid of probability ; for, not to mention that the author, whoever he was, from whom Strabo extracted this account, might, in a public exhibition, have easily mistaken polished brass for gilt copper, nor the little probability, that cauldrons, and kettles, and such vessels as were in constant use, would be gilded in any country, we have reason to believe, from what has been observed before, that a peculiar kind of vessels, probably resembling some of those exhibited in the Indian festivals, had been long in use in *Persia*, and that they were made of Indian copper without any gilding. We know that there is found in India, not only copper strictly so called, but zinc also, which being mixed with copper constitutes brass, pinchbeck, tombac, similar, and all the other metallic mixtures which resemble gold in colour. On the whole, it appears probable to me, that brass was

* Id. LXXVI,

made in the most remote ages in *India*, and in other parts of *Asia*.

With respect to Orichalcum, it is generally supposed that there were two sorts of it, one factitious, the other natural; the factitious, whether we consider its qualities or composition, appears to have been the same with our brass. As to the natural Orichalcum, there is no impossibility in supposing, that copper ore may be so intimately blended with an ore of zinc, or of some other metallic substance, that the compound, when smelted, may yield a mixt metal of a paler hue than copper, and resembling the colour of either gold or silver. In *Du Halde's* history of *China*, we meet with the following account of the Chinese *white copper*. "The most extraordinary copper is called *De-tong*, or white copper; it is white when dug out of the mine, and still more white within than without. It appears by a vast number of experiments made at *Peking*, that its colour is owing to no mixture; on the contrary, all mixtures diminish its beauty; for, when it is rightly managed, it looks exactly like silver, and were there not a necessity of mixing a little *Tutenag*, or some such metal with it, to soften it, and prevent its brittleness, it would be so much the more extraordinary, as this sort of copper is, perhaps, to be met with nowhere but in China, and that only in the
province

province of *Yun-nan*." * Notwithstanding what is here said, of the colour of this copper being owing to no mixture, it is certain, that the Chinese white copper, as brought to us, is a mixt metal; so that the ore, from which it is extracted, must consist of various metallic substances, and from some such ore it is possible that the natural Orichalcum, if ever it existed, may have been made. But, notwithstanding that the existence of natural Orichalcum cannot be shewn to be impossible, yet there is some reason to doubt, whether it ever had a real existence or not.

We know of no country in which it is found at present; nor was it any where found in the age of *Pliny*; nor does he seem to have known the country where it ever had been found. He admits, indeed, its having been formerly dug out of the earth; but it is remarkable that in the very passage, where he is mentioning by name the countries most celebrated for the production of different kinds of copper, he only says, in general, concerning Orichalcum, that it had been found in other countries, without specifying any particular country. *Plato* acknowledges, that Orichalcum was a thing only talked of even in his time; it was no where then to be met with, though in the island of *Atlantis*

* Fol. Trans. Vol. I. p. 16.

it had been formerly extracted from its mine. The *Greeks* were in possession of a metallic substance, called Orichalcum, before the foundation of *Rome*; for it is mentioned by *Homer*, and by *Hesiod*, and by both of them in such a manner as shews, that it was then held in great esteem. Other ancient writers have expressed themselves in similar terms of commendation; and it is principally from the circumstance of the high reputed value of Orichalcum, that authors are induced to suppose the ancient Orichalcum to have been a natural substance, and very different from the factitious one in use at *Rome*, and, probably, in *Asia*, and which, it has been shewn, was nothing different from our brass.

But this circumstance, when properly considered, does not appear to be of weight sufficient to establish the point. Whenever the method of making brass was first found out, it is certain that it must have been for some time; perhaps for some ages, a very scarce commodity; and this scarcity added to its real excellence as a metallic substance, must have rendered it very valuable, and intitled it to the greatest encomiums. *Diodorus Siculus* speaks of a people, who willingly bartered their gold for an equal weight of iron or copper;* and the Europeans have long carried on a similar

* Lib. III.

kind of commerce with various nations. Gold, in some views, is justly esteemed the most valuable of metals; in others, and those the most important to the well-being of human kind, it is far inferior to iron, or copper or brass. An individual, whose life depended upon the issue of a single combat, to be decided by the sword, would have no hesitation in preferring a sword of steel, to one of gold; and an army, which should be possessed of golden armour, would not scruple to exchange it, in the day of battle, for the iron accoutrements of their enemies. The preference of the harder metals to gold, is not less obvious in agriculture, than in war; a plough-share, spade, mattock, chisel, hammer, saw, nail, of gold, is not for use so valuable, as an instrument of the same kind made of iron or brass. Hence, there is no manner of absurdity in supposing that Orichalcum, when first introduced among the ancients, might have been prized at the greatest rate, though it had been possessed of no other properties, than such as appertain to brass. When iron was either not at all known, or not common in the world, and copper instruments, civil and military, were almost the only ones in use,* a metallic mixture, resembling gold in splendour, and preferable to copper, on account of its superior hardness, and being less liable to rust, must have greatly

* Hesiod.

excited the attention of mankind, been eagerly sought after, and highly extolled by them. The *Romans*, no doubt, when it had been stipulated in the league which *Porfenna* made with them, after the expulsion of the *Tarquins*, that they should not use iron, except in agriculture, must have esteemed a metallic mixture such as brass, at a rate not easily to be credited.* It is not here attempted to prove, that there never was a metallic substance called *Orichalcum*, superior in value and different in quality from brass; but merely to shew, that the common reason assigned for its existence, is not so cogent as is generally supposed.

Considering the few ancient writers we have remaining, whose particular business it was to speak with precision concerning subjects of art, or of natural history, we ought not to be surprized at the uncertainty in which they have left us with respect to *Orichalcum*. Men have been ever much the same in all ages; or, if any general superiority in understanding is to be allowed,

* In fœdere quod, expulsis regibus, populo Romano dedit *Porfenna*, nominatim comprehensum invenimus, ne ferro nisi in agricultura uterentur *Plin. Hist. Nat. Vol. II. p. 666*. Was *Porfenna* induced to prohibit the Romans the use of iron arms, from the opinion, which seems to have prevailed in Greece two hundred years afterwards—that wounds, made with copper weapons, were more easily healed, than those made with iron? *Arist. Op. L. IV. P. 43.*

it may seem to be more properly ascribed, to those who live in the manhood or old age of the world, than to those who existed in its infancy or childhood : especially as the means of acquiring and communicating knowledge are, with us, far more attainable than they were in the times of either Greece or Rome. The Compass enables us to extend our researches to every quarter of the globe with the greatest ease ; and an historical narration of what is seen in distant countries, is now infinitely more diffused than it could have been, before the invention of printing ; yet, even with these advantages, we are, in a great measure, strangers to the natural history of the earth, and the civil history of the nations which inhabit it. He who imports *Tutenag* from the East Indies, or *white copper* from *China* or *Japan*, is sure of meeting with a ready market for his merchandize in *Europe*, without being asked any questions concerning the manner how, or the place where, they are prepared in *Asia*. An ingenious manufacturer of these metallic substances might wish, probably, to acquire some information about them, in order to attempt a domestic imitation of them ; but the merchant who imports them, seems to be too little interested in the success of his endeavours, to take much pains in procuring for him the requisite information. Imitations, however have been made of them, and we have an European *Tute-*
nag,

nag, and an European white copper, differing, in some qualities, from those which are brought from Asia, but resembling them in so many others, that they have acquired their names. Something of this kind may have been the case with respect to Orichalcum, and the most ancient Greeks may have known no more of the manner in which it was made, than we do of that in which the Chinese prepare their white copper: they may have had too, an imitation of the original, and their authors may have often mistaken the one for the other, and thus have introduced an uncertainty and confusion into their accounts of it.

There is as little agreement amongst the learned concerning the etymology of Orichalcum, as concerning its origin. Those who write it *Aurichalcum*, suppose that it is an hybridous word, composed of a Greek term signifying copper, and a Latin one signifying gold. The most general opinion is, that it ought to be written *Orichalcum*, and that it is compounded of two Greek words, one signifying copper, and the other a mountain, and that we rightly render it by, Mountain Copper. I have always looked upon this as a very forced derivation, inasmuch as we do not thereby distinguish Orichalcum from any other kind of copper; most copper mines, in every part of the world, being found in mountainous coun-

tries. If it should be thought, that some one particular mountain, either in Greece or Asia, formerly produced an ore, which being smelted yielded a copper of the colour of gold, and that this copper was called Orichalcum, or the mountain copper, it is much to be wondered at, that neither the poets nor the philosophers of antiquity have bestowed a single line in its commendation; for as to the *Atlantis* of *Plato*, before mentioned, no one, it is conceived, will build an argument for the existence of natural Orichalcum, on such an uncertain foundation: and, if there had been any such mountain, it is probable, that the copper it produced would have retained its name, just as at this time of day we speak of *Eston* copper in *Staffordshire*, and of *Paris*—mountain copper in *Anglesea*.

Some men are fond of etymological inquiries, and to them I would suggest a very different derivation of Orichalcum. The Hebrew word *Or*, *Aur*, signifies light, fire, flame; the Latin terms *uro* to burn, and *aurum* gold, are derived from it, inasmuch as gold resembles the colour of flame; and hence, it is not improbable, that Orichalcum may be composed of an Hebrew, and a Greek term, and that it is rightly rendered, *flame coloured copper*. In confirmation of this it may be observed, that the Latin epithet *lucidum*, and the Greek one *φαινον*, are both

both applied to Orichalcum by the ancients; but I would be understood to submit this conjecture, with great deference, to those who are much better skilled, than I am, in etymological researches.

REMARKS *on the* ORIGIN *of the* VEGETABLE FIXED ALKALI, *with some collateral* OBSERVATIONS *on* NITRE. By M. WALL, M. D. *Prælector in Chemistry, in the University of Oxford. Communicated in a Letter to Dr. Percival. Read November 19, 1783.*

OXON, OCTOBER 1, 1783.

THE extensive employment of the Vegetable Alkali and Nitre in many of the principal operations of Chemistry, renders every inquiry into their origin and properties, not simply amusing, but interesting in a very high degree to every lover of this science, and to every one engaged in the arts dependent upon it. It is not, however, with the pretension of advancing any thing perfectly new, that I have presumed to offer the following remarks to the consideration of the Society. My hopes will be fully answered, if I should turn the thoughts of any of those ingenious Gentlemen, who have done

me the honour to associate me with them, to these subjects, so far as to lead to any new experiments, by which the qualities and preparation of articles so important may be more perfectly investigated and explained, and the great expence attending the present mode of preparing or importing them diminished.

The very curious process, discovered by Mr. Birch, and related by you, Sir, with so much perspicuity in the Philosophical Transactions, for procuring the vegetable alkali from the water of dunghills, may be adduced as a proof, that very considerable improvements have been lately made in the preparation of this salt. And as the sum paid by the nation to Russia, and other foreign states, is no less than one hundred and fifty thousand pounds per annum, for pot-ash, * every hint towards an improvement that can be suggested in its preparation, is valuable, especially as it is not impossible, that we may now also lose, in a considerable degree, the advantage of that, which has been hitherto prepared for the use of these islands in North America.

This alkali, having been long obtained solely by the combustion of vegetable substances, was by most chemists considered, as a production of the fire, formed by some secret combination of the earthy, and perhaps some portion of the in-

* *Watson's Essays*, Vol. I. p. 135.

flammable.

flammable part of the plant, with the native acid, the aqueous part being dissipated in the process.

On the other hand, it was by a few persons conjectured, that the alkali exists in vegetables perfectly formed previously to the combustion; and that the operation of the fire is nothing more, than a perfect separation and dissipation of the other principles, by which it was entangled and concealed.

In confirmation of this latter opinion, it was alledged, that Messrs. *Beaumé** and *Boulduc*,† &c. had extracted nitre, and other salts, of which this alkali is the base, from several plants by infusion and decoction, without incineration. In answer to these observations it was advanced that the nitre, &c. thus detected, must be considered as foreign, adventitious, and not essential to the plant, because from the same species the quantity obtained at different times is extremely variable. Its existence, therefore, at all in plants, must be ascribed to some peculiar circumstances of culture and soil; and in proof of this, it was remarked, that it frequently happens, that the same plants which contain much nitre, when these two circumstances favour its introduction, contain none at all in contrary circumstances.

* Dict. of Chemistry, Article, Alkali Fixed Vegetable.

† Encycloped. Art. Nitre and Mem. del Acad. des Sciences. 1734.

Of these two opinions, that which insinuates that the alkali exists in vegetables in its perfect state, can hardly be admitted, at least until we have accumulated a larger collection of facts relative to this point. It is much more probable, that the alkali, wherever it is found, whether in consequence of combustion or otherwise, is formed by some transmutation (if I may be allowed the expression) of the native acid of plants, or by a particular combination of it with the earthy and inflammable principles.

I am inclined to adopt this doctrine, from the three following circumstances, the two last of which will also shew, that this transmutation may be effected without combustion, and therefore, that this alkali cannot be any longer considered as the *creature* or *offspring* of fire.

First, Those vegetable substances, which contain the largest portion of the native acid, afford the largest quantity of alkali by incineration: and the quantity of alkali obtained is very considerably increased by particular modes of applying the heat, which can only be understood to operate, by bringing the several component principles of the vegetable substance into closer contact, and within the sphere of each other's action.

Secondly, This alkali is produced in a very considerable quantity by the process of fermentation, to which only the saccharine and acescent parts of plants are liable. And,

Thirdly,

Thirdly, It is produced in the putrefaction both of animal and vegetable matters.

In the two last of these cases, we have not indeed hitherto obtained the alkali separate, but in combination with acids forming nitrous and other neutral salts.

I. To confirm the first of the positions above stated, it is only requisite, before this Society, to observe, that no vegetable substances furnish a larger quantity of alkali than the extracts of plants, or their native essential salts. And in the common mode of preparing this alkali by incineration, it has been often remarked, that even when those vegetable substances, which abound with acid, are burnt with a close smothering heat (as in making the alkaline salt of *Tachenius*) the greatest part of the acid is gradually dissipated, and very little alkali is obtained; whereas, by a quick open fire, the acid seems to be intimately coagitated with the earthy part before such a dissipation can take place, and the produce of the alkali is vastly larger. It is a common observation, how minute a proportion of alkali the ashes of charcoal yield, compared to that which may be obtained by burning an equal quantity of the same wood in an open fire.*

II. That the vegetable alkali is produced copiously in the natural process of vinous fer-

* *Neumann's Chemistry*, by *Lewis*, Vol. II. p. 290.

mentation, appears evinced by the celebrated *Scheele's* curious analysis of the tartar of wine. *

This substance was long considered simply as a peculiar acid, debased, perhaps, by a large admixture of earthy matter: but no one before *Mr. Scheele* ever conceived, that it was a neutral salt, with a vegetable alkaline base. Yet such his experiments have shewn it to be, the alkali being, however, surperfaturated with the vegetable acid.

His principal experiment (which I relate, not as supposing it unknown to the Gentlemen of the Society, but only to recal it to their remembrance) was as follows:

He dissolved cream of tartar in a sufficient quantity of boiling water, and added fine chalk in powder to it until the effervescence ceased: a copious white sediment fell to the bottom, which was the chalk, combined with a part of the acid of tartar; and the liquor, that floated above the precipitate, afforded, by careful evaporation, a crystallization of soluble tartar, which is a compound of the acid of tartar, with the vegetable alkali. Though perfectly satisfied of the accuracy of *Scheele*, and of *Dr. Black*, who re-

* The original account of these experiments is given in the Swedish Transactions for the year 1770, but as that work is not common in this kingdom, it may be useful to refer to an Abstract of this Memoir in the Medical Commentaries, Vol. I. p. 320.

peated these experiments with the same success, I was desirous of obtaining a confirmation of this fact, by a different mode; and as I do not remember to have seen the process in any chemical work, I shall trouble the Society with an account of it.

I poured, upon an ounce of cream of tartar, nearly a pint of boiling water, and immediately added two ounces of Glauber's spirit of nitre, conceiving that the latter, by its strong attraction to the vegetable alkali (so superior to that of the acid of tartar) would, if that alkali existed in tartar, detach it from its union, and form with it a perfect nitre. Immediately upon the addition of the nitrous acid, the cream of tartar was dissolved; much sooner than might have been expected, from the quantity of water employed; but the solution was probably expedited by the change which took place upon the addition of the nitrous acid. The mixture was then set in the heat of a water-bath, and evaporated to the proper degree for crystallization; and being then placed in the cold, afforded a dram of well-formed crystals, which appeared, both by their figure and taste, and by deflagrating with charcoal, to be perfect nitre.*

From

* The quantities of the cream of tartar and spirit of nitre, used in these experiments, were taken at random, I was only solicitous to employ so much of that latter, as might

From these experiments on cream of tartar, the following conclusions result: "That this substance is not, as has been commonly supposed, a peculiar acid, joined with impurities, but that it is really a compound salt, containing an alkali joined with an acid; and further, that the alkaline salt, obtained from tartar by incineration, is not generated in the fire, but was actually pre-existent in the tartar." *

might be quite sufficient to detach all the alkali. By future trials, the proportion might be so nicely adjusted, as exactly to answer this intention, and thereby the acid of tartar might be left, after the crystallization, perfectly pure and distinct.

I evaporated the fluid remaining after the crystallization still farther, and endeavoured, by the same mode of treatment, to obtain more crystals, but without success. The evaporation was carried on, until the mass became thick and tenacious. When set in the cool, it did not deliquesce, or attract any moisture, though I kept it a fortnight in very damp weather. By this circumstance, and by the taste, I judged to be principally, almost entirely, a pure concrete acid of tartar, rendered a little more sharp and penetrating by the adhesion of a little of the acid of nitre, which probably a longer continuance, and a little increase of the heat, would have dissipated. May not these experiments, in conjunction with those of Mr. *Scheele*, (who has also shewn that the acid of tartar may be obtained pure in a concrete state) lead to an improvement in the preparation of tartar emetic?—But as this subject is not within the plan prescribed for dissertations of this kind, I shall trouble the Society with only this slight hint.

* Med. Comment. ut. supr.

III. The vegetable alkali seems also to be, in some instances, generated or formed by putrefaction; for nitre, of which it is an essential part, is often the product of a putrefactive process.

It has long been a received doctrine in chemistry, that the nitrous acid owes its origin to putrefaction: but that the alkali of nitre is derived from that source, may appear a novel opinion; and yet it is deducible from the latest observations, which have been made relative to the generation of nitre.

When it was first related by travellers from the East Indies, that nitre was there found on the surface of the ground, perfectly formed; and that it was swept up and collected for use, without any other preparation; the account was considered in Europe, as at least erroneous, and derided as inconsistent with the most established facts, concerning the formation of this salt. It was alledged that nitre, wherever produced by any thing like a natural process, is always imperfect, having a calcareous, instead of an alkaline base; that to make it perfect, a fresh solution, with the addition of wood-ashes, was indispensably requisite, both for its purification, and to supply the vegetable alkali. This, in particular, was the language of *Neumann*,* a

* *Neumann's Chemistry*, by *Lewis*, Octavo, Vol. I. p. 306.

chemist of no mean reputation, who may also, without much impropriety, be considered as a modern writer, his Dissertation on Salt Petre being published so lately as the year 1732. This doctrine, concerning nitre, cannot therefore be considered as antique, and on that account, rejected as weak and groundless.—Yet later observations have fully shewn, that this theory has been formerly too strongly insisted upon. Authentic accounts of the mode of collecting nitre in the east, very correspondent with that alluded to above, have been since received from China, and the coast of Coromandel, which are cited by Dr. *Watson*, * and prove at least (though more disputable inferences may have been drawn from them) that nitre may be formed without the assistance of art, or at least, without the addition of a vegetable alkali, or wood-ashes. The account given by Mr. *Bowles*, † of the manner in which nitre is collected in Spain, strongly confirms this assertion. In both these instances, perfect nitre is obtained from the superficial mould of the soil, only previously ploughed, and piled up in heaps. This mould or surface of the earth is formed in situations, like those above alluded to, remote from the habitations and residence of men or cattle, entirely from the

* *Watson's Essays*, Vol. I. p. 307.

† *Dillon's Translation of Don Bowles's Travels in Spain*, p. 42.

decayed and decaying parts of vegetables, advanced and advancing to the state of putrefaction. As it appears, therefore, that true nitre is produced in this process, it is obvious, that the vegetable alkali is produced by the operation of nature only, in the putrefaction of vegetables.

That nitre is produced in the putrefaction of animal matters, has been confidently asserted by some chemists, and as confidently denied by others. Instances are alledged on the one hand, of nitre procured from putrefied blood, urine, &c. On the other hand it is argued, that these substances will not supply the materials of nitre, without the concurrence of some vegetable matter. To discuss this point thoroughly, would take a great deal of time, and requires extensive abilities; but I think there is a common and familiar fact, which may be adduced to illustrate it. It will at least prove, that if nitre (and of course the vegetable alkali) is not obtainable from the putrefaction of animal matters only, the addition of a very small quantity of vegetable matter is sufficient for its production. I argue from the quality of the saline efflorescence found on old walls, which are exposed to impregnation from animal matters in a state of putrefaction. The wall of one end of my chemical school, or laboratory, is almost entirely covered with such an efflorescence. The laboratory, is a large vaulted room under ground, into which the
the

the fun seldom has admission. It is built of stone, and therefore, except when the fires are kept up for the lectures, or occasional experiments, is liable to be damp. The wall, to which I allude, is immediately under a retired passage, a very convenient place of retreat to foot-passengers under certain circumstances of necessity. The ground, therefore, and the adjacent wall have been for years largely impregnated with excrementitious animal fluids, in all the different stages of putrefaction. The saline efflorescence on such walls is sometimes supposed to be alkaline, and really to be the fossile alkali; but that in this instance, with which others of a similar sort probably have some analogy, it was perfect nitre, the following remarks will evince.

The salt deflagrates readily with charcoal, or sulphur, and leaves an alkali exactly similar in taste to that of the nitrum fixum. It does not deflagrate per se—It does not give out the smell of hartshorn, or the volatile alkali, when lixivium tartari is poured upon it either in a dissolved, or a dry state. A filtered solution of it suffers no precipitation, on the addition of lixiv. tartari. A small quantity of this solution evaporated to crystallization shoots into long, filamentous, not cubical, crystals, exactly the same as those obtained from an equal quantity of solution of nitre, by the same mode of treatment; and indeed, the efflorescence on the walls, where

it can be seen free from dust, examined with a magnifier, appears to be formed by a congeries of spicula of this oblong hexaëdral form, a mode of crystallization, which neither the fossile alkali, nor cubic nitre effect. These experiments shew, that the nitre thus collected, has neither a calcareous, nor a volatile alkaline, nor a fossil alkaline, base, but is in every respect perfect nitre, generated principally by the putrefaction of animal matters, certainly without the artificial addition of any prepared vegetable substance, (prepared at least by fire) to supply the vegetable alkali.

If you should think, Sir, upon perusal, that these observations will afford any amusement to the Society, you will oblige me by communicating them. If, on the other hand, you should think them too trifling, superficial, or tedious, I beg the favour of you to suppress them. And am,

With great regard,

Your sincere friend, and humble servant,

M. WALL.

Some

*Some ACCOUNT of the LIFE and WRITINGS of the
late PROFESSOR GREGORY, M. D. F. R. S.—
By JAMES JOHNSTONE, M. D. and Soc. Reg.
Medi. Edinb. Socius. Communicated by Dr.
Barnes. Read December 10, 1783.*

JOHAN GREGORY, M. D. F. R. S. Fellow
of the Royal College of Physicians in Edinburgh, and Professor of Medicine in the University of Edinburgh, born at Aberdeen in 1725, was third son of JAMES GREGORY, M. D. Professor of Medicine in King's College, Aberdeen; and of Anne, daughter of the Rev. George Chalmers, Principal of King's College there. The family of Dr. Gregory is of great antiquity in Scotland, and has for more than a century past produced a succession of Gentlemen, of the first distinction in the learned world. JAMES GREGORY, Professor of Mathematics, first at St. Andrews, and afterwards at Edinburgh, the Doctor's grandfather, was one of the most eminent Mathematicians of the last age, the age of Mathematics. He invented the Reflecting Telescope, improved by Sir Isaac Newton. His *Optica Promota*, and other mathematical works, are still in high esteem.

David

David Gregory of Oxford, another of the family, the Doctor's cousin, published an excellent and complete Treatise of Astronomy, founded upon the principles, and explanatory of the doctrine, of Sir Isaac Newton. James Gregory, M. D. the Doctor's eldest brother, succeeded their father as Professor of Medicine in King's College, Aberdeen: and the Doctor, of whom we write, has left a son, who now holds the office of Professor of the Institutions of Medicine in the University of Edinburgh, made vacant by the election of Dr. Cullen to be sole Professor of Practice, after his father's death. It seems to be the destiny of this family, to enlarge science, and instruct mankind; and we hope, it will long hold this honourable distinction.

Though Dr. Gregory's father died, when his son was very young, his education was carefully and successfully conducted by able and skilful persons, who were attached to his father and family, as well as to the duty they owed to their pupil. In such a happy situation for improvement, Dr. Gregory made a rapid progress in his studies. At Aberdeen, he became thoroughly acquainted with the learned languages, and with his own; here he finished his course of philosophy, and his mathematical studies; for like the rest of his ancestors, he was deeply versed in mathematical knowledge. And in this admirable school, where abstract science itself

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has undergone a signal reformation, and has learned to speak the language of common sense, and to adorn itself with the graces of taste and eloquence, Dr. Gregory cultivated an elegant and just taste, clearness and beauty of expression, with precision of judgment, and extensive knowledge. With the circle of science, he possessed a great share of common sense, and of the knowledge of men. This he displays in his writings; and evidently carried into his profession a spirit congenial to that of the Gerards and Beattie's, Gentlemen, with whom he lived in the closest habits of friendship.

Having finished at Aberdeen his course of study in languages, arts, and philosophy, in 1742 he went to Edinburgh, to prosecute the study of medicine.

Having attended the excellent courses of the late Dr. Alexander Monro, the celebrated Professor, and Father of Anatomy there—of Dr. Alston, on the *Materia Medica*, and Botany—of Dr. Plummer, on Chemistry—of Dr. Sinclair, the elegant and favourite scholar of Boerhaave, on the Institution of Medicine—of the sagacious Rutherford, on the Practice of Medicine—he went to Leyden in 1745, and to Paris in 1746, for farther improvement.

While at Leyden, he received a spontaneous mark of the esteem in which he was held by those among whom, and by whom, he had been educated,

cated, in having the degree of Doctor of Physic conferred upon him by the University of Aberdeen; and when he returned there from Paris, he was appointed Professor of Philosophy in King's College. He held this professorship for three or four years, and during that time he gave lectures, or rather a complete course, according to the method of education in that university, on the following important branches of knowledge. 1. Mathematics. 2. Natural and Experimental Philosophy. 3. Ethics, and Moral Philosophy.

In 1754 he went to London, where he was chosen Fellow of the Royal Society, and cultivated the acquaintance, and fixed the esteem and friendship, of some of the most distinguished literati there. Edward Montague, Esquire, an eminent mathematician, and worthy man, maintained a firm friendship for the Doctor, founded on the similarity of their manners and studies. His Lady, Mrs. Montague, and George Lord Lyttelton, were of the number of his friends; and it is not improbable but he would have continued in London, and practised there in his profession, if the death of his brother James Gregory, M. D. and Professor of Physic in King's College, Aberdeen, in 1756, had not occasioned his being recalled to his native university, to fill the chair of Professor of Physic; vacant by his brother's death. His occupations in physic

now began to be active: he gave a course of lectures in physic, and practised in his profession, with universal applause.

In 1766, on the mournful occasion of the death of Dr. Robert Whytt, the ingenious Professor of the Theory of Physic at Edinburgh, Dr. Gregory was called to succeed him, as his Majesty's first Physician in Scotland; and, about the same time, he was chosen to fill the chair of Professor of the Practice of Physic, which was just resigned by Dr. Rutherford; the Trustees of that University being ever attentive to support the high reputation of the celebrated school of physic there, by drawing to it, from every quarter, physicians of the most approved talents and qualifications in the several branches of medicine, they are appointed to teach. Dr. Gregory gave three successive courses of practical lectures. Afterwards, by agreement with his ingenious colleague, Dr. Cullen, they lectured alternate sessions, on the Practice and Institutions of medicine, with just and universal approbation, till the time of Dr. Gregory's death.

The doctor having attained the first dignities of his profession in his native country, and the most important medical station in the university, far from relaxing from that attention to the duties of his profession which had raised him, endeavoured to merit the rank he held in it, and in the public esteem, by still greater exertions

exertions of labour and assiduity. It was during this time of business and occupation, that he prepared and published his Practical Syllabus for the Use of Students, which, if it had been finished, would have proved a very useful book of practice; and likewise, those admired Lectures on the Duties, Office, and Studies of a Physician.

Dr. Gregory, for many years before his death, felt the approach of disease, and apprehended, from an hereditary and cruel gout, the premature death, which, indeed, too soon put a period to his life and usefulness. In this anxious expectation, he had prepared that admirable proof of paternal solicitude and sensibility, "A Father's Legacy to his Daughters." But for some days, and even that preceding his death, he had been as well as usual; at midnight, he was left in good spirits by Dr. Johnstone, late Physician in Worcester, at that time his Clinical Clerk; yet, at nine o'clock in the morning of the tenth of February 1773, he was found dead in his bed.*

* He too, Dr. Johnstone, junior, of Worcester, has lately fallen a much lamented martyr to a noble discharge of duty, in attending the prisoners ill of a fever in Worcester jail (1783). He attained, at an early period, to great and deserved eminence in his profession: and will be ever regretted as a physician of great ability and genius, and as one of the most pleasing and benevolent of men; prematurely snatched from his friends and country, when become highly agreeable and useful to them.

Dr. Gregory was tall in person, and remarkable for the sweetness of his disposition and countenance, as well as for the ease and openness of his manners. He was an universal and elegant scholar, an experienced, learned, sagacious and humane physician—A professor, who had the happy talent of interesting his pupils, and of directing their attention to subjects of importance, and of explaining difficulties with simplicity and clearness. He entered with great warmth into the interests and conduct of his hearers, and gave such as deserved it every encouragement and assistance in his power: open, frank, social, and undisguised in his life and manners, sincere in his friendships, a tender husband and father: an unaffected, cheerful, candid, benevolent man—a faithful christian. Dr. Gregory's unexpected death, in the height of his usefulness, and with appearances which afforded hopes of its continuance for a much longer period, was universally lamented as a public, no less than a private loss; and science, genius, and worth will long weep over his grave.

Dr. Gregory married in 1752, Elizabeth, daughter of William Lord Forbes: he lost this amiable lady in 1761: she left the doctor three sons and three daughters, viz. James Gregory, M. D. now Professor of Medicine in Edinburgh—Dorothea—Anne—Elizabeth—William, student of
of

of Baliol College, Oxford, and now in orders :—
John—all now living, except Elizabeth, who
died in 1771.

HIS WORKS.

I. COMPARATIVE VIEW of the State and Faculties of MAN with those of the ANIMAL WORLD.

This work was first read to a private literary society at Aberdeen, and without the most distant view to publication. Many hints are thrown out in it on subjects of consequence, with less formality, and more freedom, than if publication had been originally intended. The size of the book may have suffered by this circumstance; but the value of the matter has probably been increased, by a greater degree of originality, and of variety. The author indulges himself in the privileges of an essayist; he touches many interesting subjects, but with a masterly, a bold, yet a judicious hand. This work, like another of great fame, may be called a chain, the links of which are very numerous, and yet all connected together. We know the author the better for the rapid judgment he passes, and cannot help admiring the goodness of his heart, and the benevolence of his views, which have an obvious direction to raise the genius, and to mend the heart; and we concur with him in thinking that, “ That

view of human nature may be the safest, which considers it as formed for every thing that is good and great, and sets no bounds to its capacity and power; but looks on its present attainments as trifling, and of no account.

The comparative anatomy of brute animals has (as observed by our author) been the source of most useful discoveries in the anatomy of the human body; but the comparative animal œconomy of mankind, and of other animals—comparative views of their states and manner of life, have been little regarded. Instinct is a principle common to us, and the whole animal world: to animals, as far as it extends, it is an infallible guide—In man, reason is but a weak principle, and an unsafe guide, when compared to instinct. Of this, curious instances are mentioned. In the bringing forth, and in the nursing of their young, the advantages of brute instinct over the customs which have been taken up by rational beings, are placed in a strong light. Numbers of mothers, as well as infants, die by the management of preposterous art in child-bearing, and afterwards, by mothers omitting the duty of nursing—A natural duty and obligation, which contributes no less to the safety, health, and beauty of mothers, than it does to preserve the lives and health of their offspring.

The

The recent improvements which have been made in the art of midwifery, and in the methods of nursing children, are owing to the observations of nature, and the imitation of its instinctive propensities.

In this first discourse, our author proposes many improvements of the health and faculties of the human race, by deserting a luxurious and artificial, and following a natural course of life. In this manly way of thinking, he is constantly assisted by keeping in view the natural history of animals, and the manners of savage nations, which resemble them, in following their instinctive propensities.

In the succeeding discourses, in which he treats with great perspicuity, taste, and discernment, of the superior faculties which distinguish man from the rest of the animal creation, and of the sciences and arts founded upon them, he diverges from this comparative view, and loses sight of the inferior part of the creation, until he arrives at the following conclusion of this entertaining and ingenious work. “ The advantages which arise to mankind from those faculties which distinguish them from the rest of the animal world, do not seem correspondent to what might be reasonably expected from a proper exertion of these faculties, not even among the few who have the greatest abilities, and the greatest leisure to improve them. The capital
error

error seems to consist, in such men confining their attentions chiefly to inquiries, that are either of little importance, or the materials of which lie in their own minds. The bulk of mankind are made to act, not to reason, for which they have neither abilities, nor leisure. They who possess that deep, clear, and comprehensive understanding which constitutes a truly philosophical genius, seem born to an ascendancy and empire over the minds and affairs of mankind, if they would but assume it. It cannot be expected, that they should possess all those powers and talents which are requisite in the several useful and elegant arts of life; but it is they alone, who are fitted to direct and regulate the application."

The author put his name to the second edition of this work; many additions are also joined to it; and it is dedicated to George Lord Lyttelton, who always professed a high esteem for the author and his writings. This work, in fine, if the author had left no other, must convince every one, that, as a man of science, he possessed extensive knowledge, exquisite taste and judgment, and great liberality of mind and thought; and that, as handsomely said by our instructive poet, Mr. Hayley, in quoting this engaging little volume, in his *Essay on Writing History*. "He united the noblest affections of the heart to great elegance

elegance of mind; and is justly ranked amongst the most amiable of moral writers."

II. OBSERVATIONS on the DUTIES and OFFICES of a PHYSICIAN, and on the Method of PROSECUTING ENQUIRIES in PHILOSOPHY.

This work was first published in 1770, by one, who heard the Professor deliver them in lectures; but they were acknowledged, and republished in a more correct form, by the author, in 1772. In the first lecture, the Professor, in representing what the character of a physician ought to be, displays the most noble and generous sentiments on that subject; and all that knew him allow, that no one bore a more exact resemblance to the fine picture which he here draws, than himself.

"The true dignity of physic is to be maintained, by the superior learning and abilities of those who profess it, by the liberal sentiments of Gentlemen, and by that openness and candour which disdain all artifice, which invite a free inquiry, and which, by this means, boldly bid defiance to all that illiberal ridicule and abuse, which medicine has been so much exposed to."

In the second lecture, he shews the method of prosecuting inquiries in philosophy, with an obvious direction to medicine, as one of its principal branches.

III. The next work published by Professor Gregory is intitled, ELEMENTS of the PRACTICE
of

of PHYSIC for the use of STUDENTS, 1772, re-published 1774.

The Doctor intended this work as a TEXT BOOK, to be illustrated by his lectures on the practice of physic; but he died before he had finished it, and before he had finished the first course of lectures, which he gave on that text. It is written with great perspicuity and simplicity: the author has intentionally avoided systematical arrangement, perhaps from an opinion, that the art of medicine was yet in too imperfect a state, to admit of any perfect systematical form. However this may be, the work evidently displays the author's great fitness to teach that art. A truly practical genius appears conspicuously in that part of the book, which is thrown into interrogations. Into these, our sagacious author has thrown every thing which had importance to require peculiar attention, as well as those things, which are still matters of doubt and uncertainty, in the practice of medicine.

The Doctor's death happened while he was lecturing on the Pleurisy. His son, Dr. James Gregory, finished that course of lectures, to the general satisfaction of the University; and he therein gave ample proof of his fitness for the station of Professor of Medicine, which he now fills with great honour to himself, and to the University—*Non deficit alter aureus.*

This

This Gentleman published in 1774, a small tract of his father's, entitled "A FATHER'S LEGACY TO HIS DAUGHTERS:" which was written solely for their use (about eight years before the author died) with the tenderest affection, and deepest concern for their happiness. This work is a most amiable display of the piety and goodness of his heart, and his consummate knowledge of human nature, and of the world. It manifests such solicitude for their welfare, as strongly recommends the advice which he gives. He speaks of the female sex in the most honourable terms, and labours to increase its estimation, whilst he plainly, yet genteely and tenderly, points out the errors into which young ladies are prone to fall. It is particularly observable, in what high and honourable terms he speaks of the Holy Scriptures, of christian worship, and faithful ministers; how warmly he recommends to his daughters the serious and devout worship of God, in public and private. He dwells largely on that temper and behaviour, which were particularly suited to their education, rank, and circumstances; and recommends that gentleness, benevolence, and modesty, which adorn the character of the ladies, and do particular honour to their sex. His advices, with regard to love, courtship, and marriage, are peculiarly wise, and interesting to them. They shew what careful observation he had made on female domestic

mestic conduct, and on the different effects of possessing or wanting the virtues and qualities which he recommends. There is something peculiarly curious, animated, and useful, in his directions to them, how to judge of, and manifest an honourable passion in, and towards the other sex, and in the very accurate and useful distinction which he makes, between true and false delicacy. Nothing can be more striking and affecting, nothing more likely to give his paternal advices their desired effect, than the respectful and affectionate manner in which he mentions his lady their mother, and the irreparable loss which he and they sustained by her early death. In short, in this tract, the Professor shines with peculiar lustre, as a husband and father, and it is admirably adapted to promote domestic happiness. It is much to be wished, that this tract was re-printed in a cheaper form, that it might be more generally read and regarded. And also, that the Doctor's works were re-printed together.

“ Adieu, ye lays, that fancy's flowers adorn,
The soft amusement of the vacant mind !
He sleeps in dust, and all the Muses mourn ;
He, whom each virtue fired, each grace refined,
Friend ! teacher ! pattern ! darling of mankind !
He sleeps in dust !—Ah ! how should I pursue
My theme !—To heart-consuming grief resigned,
Here on his recent grave I fix my view ;
And pour my bitter tears—Ye flowery lays adieu !

Art thou, my Gregory, for ever fled!
And am I left to unavailing woe!
When fortune's storms assail this weary head,
Where cares long since have shed untimely snow,
Ah! now for comfort whither shall I go!
No more thy soothing voice my anguish cheers:
Thy placid eyes with smiles no longer glow,
My hopes to cherish, and allay my fears,—
'Tis meet that I should mourn—Flow forth afresh
my tears!" *

* Beattie's *Minstrel*, second Book, concluding stanzas.

*On the KNOWLEDGE of the ANCIENTS respecting
GLASS, with a SKETCH of its HISTORY down
to later TIMES. By Dr. FALCONER. Read
December 17, 1783.*

Ante Christum,
Ann. 440.
Herodotus.

HERODOTUS is, I believe, the
most ancient writer, in whom
the word *υαλος*, which is generally
understood to signify glass, occurs. He says,
that "the Æthiopians surrounded the dead
bodies of persons of high rank, after being pre-
viously embalmed, with a case of glass; which
substance, he adds, is dug up there with ease,
and in plenty. The dead body, he says, appears,
in

in the middle, through the transparent covering, neither emitting any ill scent, nor being otherwise disagreeable."* It appears, plainly, that artificial glass could not be meant here, nor as I should conjecture, rock chrystal, but in all probability somewhat of the talky kind or lapis specularis, which might easily be framed, in such a manner, as to form a convenient transparent case, such as is here described.

A. C. 400. The next writer, in point of time, Aristophanes. that takes notice of glass is, I believe, Aristophanes, who, in the first scene of the second act of his Comedy of the Clouds, introduces Strepsiades an old Man, much in debt, informing Socrates of a method he had discovered of annulling his own debts.

"You have seen, says he, among the druggists or perfumers, a stone which is beautiful and transparent, and used to kindle fire. Do you mean glass? answers Socrates. I do, replies the other. What will you do with it? says Socrates. When, the other answers, the Scribe shall have

* Μετα δε ταυτην, τελευταίας εδησαντο τας θηκας αυταις, αι λεγονται σκευαζισθαι εξ υελου, τροπω τωιδε. Επεια τον νεκρον ισκηνηωσι, ειτε δη καδαπερ Αιγυπιοι, ειτε αλλως κως, γυψωσαντες απαντα αυτον, γραφη κοσμεουσιν, εξομοιουντες το ειδος ες το δυνατον· επειτα δε οι περιμισασι στήλην εξ υαλου πεποιμνηνην κοιλην. η δε σφι πολλη κ' ευερος ορυσσεται. εν μηση δε τη σήλη ενεων διαφαινεται ο νεκος, ουτε οδμην ουδερμην ακαριν παρεχομενος, ουτε αλλο αεικες ουδεν. κ' εκει πανταφα.ερα ομοιως αυτω τω νεκρῳ. Herod. L. III.

written out the process, I, taking this in my hand, and standing in this manner at a distance, opposite to the Sun, may melt or consume the letters of the writing.” *

We are not, indeed, certain that artificial Glafs is here understood, as the word *υαλος* is said to signify chrystal also.

It is not, however, at all improbable that glafs may be here meant, as it will be shewn, that the making of it was well understood, not many years afterwards. If this be the sense of the passage, the manufacture must have been brought to considerable perfection, as the glafs, used for this purpose, must have been very clear, and adjusted by grinding to a proper form for concentrating the sun’s rays, and moreover highly polished.

From the expression (*προς τον ηλιον*), it might seem that a speculum was used, since the translators render it (*adversus solem*) opposite to the sun; but it may as well be rendered (*inter*) between, and then it agrees with the operation of a lens, which, it is plain, this was, from his calling it

* Στρ. Ηδε παρα τοις φαρμακοπώλαις την λιθον ταυτην εῶρας την καλην, την διαφανη. αφ’ ἧς το πυρ ἀΐπτεισι; Σω. την υαλου λεγεις; Στρ. Εγωγε. Σω. Φερε τι δητ’αν; Στρ. Ειταυτην λαβω, οποτε γραφοιτο την δικην ο γραμματευσ, αποτερω σλας ωδε προς τον ηλιον, τα γραμματα εντηξαιμι της εμης δικης.

Aristoph. Nubes, A& II. Scene I.

διαφανη, or transparent.—Aristophanes,* in other places, mentions glass cups, as used for the purposes of drinking.

A. C. 340. Aristotle has two problems, relative to glass. The first endeavouring to explain its transparency, the second, its want of malleability. But the learned think them both to be spurious. There is, however, no doubt, that Theophrastus, the immediate successor of Aristotle, was well acquainted with glass. He describes it as being made of the sand of the river Belus, † which was called *Υελις*, to which he adds, that the commonest kinds were mixed with copper. The celebrated sphere of Archimedes, ‡ if truly described, is a remarkable instance of the perfection to which the art of making glass had been brought, at an early period,

* *Επειον ο μεν εξ υαλιων εκποματων.* Aristoph.

† *Ει δε υελος εκ της υελιδος ως τινες φασι χ' αυτη πυκνωσει γινεται· ιδιωτατη δε η τω χαλκω μιγνυμενη.* Theophr.

Ita (*υελις* scilicet) vocant arenam vitro conflando idoneam, quæ in Beli amnis ripis & alveo reperiebatur.

Salmasius. Plin. Exerc. p. 773.

‡ An Archimedes Siculus concavo ære similitudinem mundi, ac figuram potuit machinari, in quo ita solem, ac lunam composuit; ut inæquales motus & cælestibus similes conversionibus, singulis quasi diebus efficerent: & non modo accessus solis, & recessus, vel incrementa, diminutionesque lunæ,

period, as well as of great ingenuity in the mechanism and execution of the instrument itself. It seems to have been a kind of orrery or planetarium, in which the sun, moon, and planets, were not only represented in their proper places,

lunæ, verum etiam stellarum vel inerrantium, vel vagarum dispares cursus orbis ille dum vertitur, exhiberet ?

Lactant. Lib. II. De Orig. Erroris.

Hic est ille noster, cujus ingenio sphæra fabricata, cæli lapsus, & omnium syderum cursus, exemplo divinæ imitationis ostendit. *Jul. Firmic. L. VI. Cap. 31.*

Claudiani Epigramma in Sphæram Archimedis.

Jupiter in parvo cum cerneret æthera vitro,

Risit, & ad superos talia dicta dedit :

Huccinè mortalis progressa potentia curæ ?

Jam meus in fragili frangitur orbe labor.

Jura poli, rerumque fidem, legesque Deorum

Ecce Syracosius transtulit arte senex.

Inclusus variis famulatur Spiritus astris,

Et vivum, certis molibus urget opus.

Percurrit proprium mentitus signifer annum,

Et simulatâ novo Cynthia mense redit.

Jamque suum volvens audax industria mundum,

Gaudet, & humanâ sidera mente regit.

Quid falso infontem tonitru Salmonea miror ?

Æmula naturæ parva reperta manus.

Nam quum Archimedes lunæ, Solis, quinque errantium motus in Sphærâ illigavit, effecit idem quod ille qui in Timæo mundum exædificavit Platonis Deus, ut tarditate & celeritate dissimillimos motus una regeret conversio.

Cicer. Tusc. Quæst. Lib. I.

according to the astronomical ideas that then prevailed, but also made to move in their orbits according to their different degrees of velocity. The meridians, the zodiac, with its signs, and other great circles of the heavens, together with the rise and setting of the stars, were all expressed. The whole of this curious mechanism, was inclosed in glass, and seems to have been in form of a sphere. Whether the celestial circles, together with the fixed stars, were delineated on the outer glass covering, which might be made to revolve round the rest of the planetary system, like that described in the first volume of Dr. Long's *Astronomy*, and the print of it prefixed to the title of that book; or whether it was constructed in any other manner, is not clear. It must, at any rate, have been a surprising piece of mechanism.

A. C. 105. Lucretius was undoubtedly well acquainted with glass, and its properties. In his fourth book, he remarks the difference between sounds, and the images of objects. The former passing through any openings however curved or winding, * whilst the latter are broken and confused, if the passages,

* -----Vox per flexa foramina rerum
Incolumis transire potest, simulacra renutant.
Perfcinduntur enim, nisi recta foramina tranant,
Qualia sunt vitri, species quæ travolat omnis.

Lucret. L. IV. Lin. 603:

through which they come, be not direct or rectilinear.

This, though only true, with some limitations, shews him to have had no inconsiderable knowledge of the nature of the subject in question.

A. C. 39. Virgil,* when he means to commend the clearness of the Fucine lake, compares the water of it to glass; a circumstance which shews the clear kinds of glass to have been well known in his time.

A. C. 36. Horace† is more express, and mentions glass in terms, that shew its clearness and brightness to have been brought to great perfection. In particular, he compares the fountain of Blandusia to glass, and says it was even brighter than that substance; an expression that carries great force, no glass at present possessing that quality, in a higher degree, than some spring waters.

Post
Christum. In the time of Strabo, the making
A. D. 27. of glass was undoubtedly well under-
quo Strabo stood, and had become a great article
obiit. of manufacture, as appears from the
following account given by this author:

* Vitreâ te Fucinus undâ

Te liquidi flevère lacus.

Virg. *Æneid.* VII. 759.

† Perlucidior vitro.

Hor. *Carm.* III. Ode II.

Splendidior vitro.

Hor. *Carm.* III. Ode XIII.

“Between Ace, (or Ptolemais) and Tyre, the shore abounds with small eminences, which are composed of a vitrifiable earth. They say, however, that it is not melted there, but brought to Sidon to undergo that operation. Some say, that the Sidonians have a vitrifiable sand fit for fusion; others say the sand which is commonly found, is used for that purpose. I, myself, have heard (says Strabo) from the manufacturers of glass at Alexandria, that there is a certain vitrifiable earth in Egypt, without which, the most magnificent, and variously coloured pieces of manufacture cannot be made, as the different kinds of glass require different mixtures of ingredients. Many discoveries also were made at Rome, both with regard to the beauty of the colour, and also as to the facility of execution, especially in those kinds of glass that are made to resemble chrystal.”

Seneca* was not only well acquainted with glass as a substance, but also understood its magnifying powers when formed into a convex shape.

A. D. 65. A glass globe, says he, filled with water, makes letters viewed through it, appear larger and brighter. The magnifying power of glass considered as a more dense, and of course a more refrangible medium than air, was not unknown

* Literæ quamvis minutæ & obscuræ per vitream pilam aquâ plenam majores clariorefque cernuntur.

Senec. *Quæst. Natur.* I. 6.

to him. Fruits, * says he, viewed through glafs, appear much larger, and more beautiful. The stars also appear magnified in a humid atmosphere. If a ring be put into a bowl of water, and viewed there, it seems to approach to the eye, or in other words, is magnified; which the same author observes, is the case with every body that is viewed through a fluid. Seneca† says here expressly, that water, as a medium, has the same effect with glafs. It is worthy remark, that the effect of the prism in exhibiting the original colours that are combined in light, was a fact well known in the time of Seneca; and from his expression, we may conjecture the experiment to have been frequently practised. “A rod of

* *Poma per vitrum aspicientibus multo majora sunt.*

Senec. *Quæst. Nat. I. 3.*

† *Poma formosiora quam sint videntur, si innatant vitrò. Sidera ampliora per nubem aspicienti videntur: quod acies nostra in humido labitur, nec apprehendere quod vult fideliter potest. Quod manifestum fiet, si poculum impleveris aquâ, & in id conjeceris annulum. Nam cum in ipso fundo jaceat annulus, facies ejus in summo aquæ redditur. Quicquid videtur per humorem longe amplius vero est. Quid mirum, majorem reddi imaginem Solis, quæ in nube humidâ visitur, cum de causis duabus hoc accadat: quia in nube est aliquid vitro simile quod potest perlucere, est aliquid & aquæ, quam si nondum habet, tamen jam apparet ejus Natura, in quam ex suâ vertatur?*

Senec. *Quæst. Natur. L. I. C. 6.*

glass, * says he, is commonly made, drawn out, or swelling with many angles in form of a club : this, says he, if the rays of the sun fall upon it in a transverse direction, exhibits the same colours as we are accustomed to see in the rainbow." This curious passage has not been sufficiently attended to by the commentators.

Petronius Arbiter, in his account of A. D. 66. the feast † of Trimalcio, makes him Mors. Petronii. relate a story of "an artificer, who could make vessels of glass of such a degree of tenacity as not to be more liable to be broken than if made of gold or silver. Having made a drinking cup of the purest glass of this kind, which he thought no one worthy to possess but the Emperor, he was admitted into his presence, in order that he might offer this specimen of his ingenuity for the Emperor's acceptance. The nature of his present met with praise; the hand of the artificer was commended, and the respect he shewed by it, found a favourable reception. The artist, however, being desirous to heighten

* *Virgula solet fieri vitrea, stricta, vel pluribus angulis in modum clavæ torosa; hæc si ex transverso solem accipit, colorem talem qualis in arcu videri solet, reddit.*

Senec. Quæst. Natur. Lib. I. Cap. 7.

† This passage from Petronius is to be found in Joannes Sarisburiensis.

Polycrat. L. IV. Cap. 5, and literally translated.

their

their admiration into surprize and astonishment, and to conciliate more effectually the favour of the Emperor, requested the cup again from his hand; and having received it, threw it with all his force upon the pavement in so violent a manner, that it could not have escaped injury, had it been made of the most solid and uniform brass. The Emperor, at the sight of this action, was no less astonished than concerned; but the artist taking up the cup from the ground, which was not broken, but only bruised by the blow it received, which had the same effect upon it as it would have had if the cup had been made of copper; and drawing forth a hammer from his bosom, repaired the bruise that the glass had received, by hammering it with frequent strokes, much in the same way as if the cup had been of brass. The expectations of the artificer were much raised by the success of this operation, which had introduced him to the knowledge of the Emperor, and procured him general admiration; but the event turned out different from what he imagined; for the Emperor enquiring of him, if any one else was acquainted with the secret of preparing glass in such a manner; and he answering in the negative, his head was ordered to be struck off, the Emperor assigning for a reason, that if this secret should be made publick, gold and silver would lose their value, and become of no more estimation than clay."

It

It is difficult to guess what the composition of the substance here called glass could be. It certainly could not be any vitrified body as such are universally brittle. Some have thought it to have been the luna cornea, or the calx of silver, made by the dissolution of that metal in the acid of nitre, and its precipitation by that of salt. But this, though endued with considerable flexibility and tenacity, is not malleable to the degree here represented.

Pliny, however, appears to have left
 A. D. 77. us the most complete information con-
 Plinius cerning glass. He mentions it as be-
 obiit. ing of Phœnician origin, as many other
 great discoveries have been. It was first made of sand found in the river Belus, a small river of Galilee, running from the foot of Mount Carmel, out of the lake Cendevia. The part of the shore where the sand was dug, did not exceed 500 paces in extent, and had been used many ages before, for the same purpose. The report of its discovery was, that a merchant ship laden with nitre, or fossil alkali, being driven upon the coast, and the crew going ashore for provisions, and dressing their victuals upon the shore, made use of some pieces of fossil alkali to support their kettles. By these means a vitrification of the sand beneath the fire was produced, which afforded a hint for the manufacture. In process of time the calx of iron, in form of the magnetical stone, came

came to be used along with the fossil alkali, from an idea of its not only containing iron, but glass in a liquid form. Clear pebbles, shells, and fossil sand, were also in many places employed for the same purpose. It is said, that in India, pieces of native chrystal were used for that purpose; and on that account, the Indian glass was preferred to any other. He adds, that light and dry woods were used for the melting of glass; to which they added copper from the island of Cyprus, and the fossil alkali, especially that which is brought from the East Indies. The furnaces are kept burning without intermission, that the copper may be melted with the glass, and out of this compound are made masses of a coarse blackish colour. These lumps or masses are again melted, and tinged of the colour required. Some of these pieces are brought to the shape desired, by blowing it with the breath: some are ground in a lathe, and others are embossed in the same manner with silver. Sidon was formerly famous for these manufactures, as specula or looking glasses were first invented there. The above is described by Pliny, as the ancient method of making glass. In his time, it was made with sand found at the mouth of the river Vultur-nus, upon the shore, for six miles between Cumæ and the Lucrine Bay. This sand was very fine, and was ground to powder with a ball or sphere, and
a mill

a mill. It was then mixed with three parts of the fossil alkali, either by weight or measure; and being fused, was conveyed in a liquid state into other furnaces, where it was formed into a mass called ammonitrum (or sand combined with the fossil alkali), which mass was melted, and became then pure glass, and a mass of white vitrified matter. The same method of making it, prevailed in Spain and Gaul. Glass was likewise made to imitate the lapis obsidianus, a substance found by a person of the name of Obsidius, in Egypt and Æthiopia. It was of a very black colour, yet obscurely transparent, and often placed among specula, in the walls of rooms, to reflect the shadow of objects. It was also used for the same purpose as gems (I apprehend for engraving upon) and even for statues, Pliny mentioning, that he saw solid statues of the Emperor Augustus, made of this material; and the same Emperor dedicated four elephants made of the same substance in the Temple of Concord. It appears to have been used from great antiquity, since Tiberius Cæsar, when he governed that country, found a statue of Menelaus, made of it. In the time of Pliny, the artificial imitation of it by glass, seems to have been in use instead of the native material. Pliny seems to intimate, that the black colour given to the glass that was made to imitate the lapis obsidianus, was produced

duced by some colouring ingredient.* But many stones commonly found, as the gray rag stone, the blue whin stone, the Derbyshire toad stone, and the Westmoreland slate, will all melt into a vitreous mass of a black colour. I was informed by his Grace the late Duke of Northumberland, whose knowledge in chemistry, and natural history, was very extensive, that he once procured a pot of glass to be made at the Glasshouse at Newcastle upon Tyne, of the whin stone. The glass produced from it, was of a fine black colour, and good uniform texture, and easy fusion; but inconvenient to be used for bottles, on account of its having scarcely any transparency. He likewise added, that it exactly resembled some specimens of what was imagined to be the ancient lapis obsidianus.

The Romans had likewise an opaque red kind of glass, used for plates and dishes for the table, called hæmatinon, one of various colours called myrrhinum, a white, a clear red, a blue, and indeed most other colours. Pliny observes of it, that no substance was more manageable in receiving colours, or being formed into shape than glass.

The perfectly clear glass, which bore the greatest resemblance to chrystal, was, however, most valued. Nero gave for two cups, with two

* Plin. Hist. Nat. L. XXXVI. Cap. 26.

handles to each, and of no extraordinary size, six thousand sesteritia, or nearly fifty thousand pounds sterling. But although the finer kinds appear to have been so rare and valuable, the inferior kinds must have been not uncommon, since Pliny says, that the use of glass cups had nearly superseded those of gold and silver.—Pliny likewise knew the power of a hollow glass globe, filled with water, in concentrating the rays of light, so as to produce flame in any combustible substance upon which the focus fell; and also mentions, that some surgeons in his time, made use of it as a caustic * for ulcers. He was likewise acquainted with the comparative hardness of gems and glass, as he observes, that the lapis obsidianus would not scratch the true gems; and † he also mentions the counterfeiting of the latter in his time, as a very lucrative art, and brought to great perfection. The same author mentions, that glass might be cut or engraved upon by means of diamonds, which art is evidenced by the antique gems so frequently found.

The ruins of the city of Pompeia, which was destroyed in the time of Pliny, have
A. D. 77. afforded examples of the use of glass in windows. I was informed by a gentleman of accuracy, that he had measured a pane of glass

* L. XXXVII. Cap. 2.

† L. XXXVII. Cap. 13.

found in a window there, and it amounted to eighteen inches long, by about fourteen wide.

The* inspired writer of the Apocalypse, describing the brightness of one of the appearances in his vision, calls it "a sea of glass, like unto chrystal."

Josephus† the Jewish historian says, that "near the monument of Memnon, which lies on the river Belus in Galilee, there is a place an hundred cubits in extent, worthy admiration. It is (adds this writer) round and hollow; and although it be exhausted by the numerous ships that touch there, it is soon filled again; the winds as it were, by design, tearing up the white sand from other places, and bringing it hither, and the mine itself, has the power of changing the sand that is thus carried into it, into glass; and what seems to me more extraordinary, the glass that over-

* Θαλασσα υαλινη ομοια κρυσταλλω. Apoc. C. 4. V. 6.

† Του δε ασίως απο δυω σταδιων ο καλουμενος Βηλειος ποταμος παρρει πανταπασιν ολιγος, παρ ὧ το Μεμνονος μνημειον εστιν, εχον εγγυς αυτου τοπον εκατοντα πηχην θαλασσης αξιον, κυκλοτερης μιν γαρ εστι και κοιλος, αναδιδωσι δε την υαλινην ψαμμον, ην οταν εκκνωση πολλα πλοια προσχοντα, παλιν αναπληρουνται το χωριον κατασυροντων μιν ωσπερ επιτηδες τοτε τον ανεμων εις αυτο την εξωθεν αεργην ψαμμον, του δε μεταλλου πασαν ευθειας μεταβαλλοντος εις υαλον, θαλασσιωτερον τουτο μοι δοκειν, το την υπερχυθεισαν υαλον, παλιν γενισθαι ψαμμον εικαιαν. Joseph. L. II. C. 10.

flows

flows from this place, becomes again common sand." It is evident, that Josephus here, by the word *υαλος*, means only the sand fit for the making of glass.

In the time of Martial, glass was not
A. D. 84. only brought to great perfection, and in
Martial. common use * for drinking vessels, but was also employed (as it seems) for † bottles in which wine was kept, and likewise for ‡ pots to hold flowers.

A few words on the antiquity of the term (glass) may not in this place be improper. Tacitus and Pliny § inform us, that amber was called among the ancient Gauls and Germans, by the name of *glesum* or *gleffum*; and from the similarity which glass bore to amber in point of

* Nos bibimus vitro, tu myrrha Pontice, quare?
Prodat perspicuus ne duo vina calix.

Martial Epig. L. IV. Ep. 86.

† Condantur parco fusca falerna vitro. L. II. Epig. 40.

‡ Condita sic puro numerantur lilia vitro.

L. II. Epig. 22.

§ Succinum quod ipsi gleffum vocant inter vada atque ipso in litore legunt. Taciti German. C. 45.

Certum est gigni in insulis septentrionalis Oceani & a Germanis appellari gleffum itaque & a nostris unam insularum ob id gleffariam appellatam.

Plin. Hist. Nat. Lib. XXXVII. Cp. 3:

transparency

transparency and brightness,* it acquired a name which was in all probability, originally the same.

The word *glesum* implied no doubt a shining or transparent substance; *gleissen* expresses at present in the German language, to shine; and our English word to *glisten* is derived from it, and has nearly the same signification. Du Cange † says, that some critics were of opinion, that the word *glesum* itself, implied glafs rather than amber. It is farther remarkable, that the ancient Greeks applied the same term (*Ηλεκτρον*), || both to glafs and amber.

The herb wherewith the Britons painted their bodies, went also under the name of

* Antiquis Germanis fuisse *gleffum* auctores sunt Plinius atque Tacitus quamquam apud hunc perperam legitur *glesum* unico s nam ipsis Germanis fuit *glefs* quo vocabulo postea paulum variato in *glafs* vitrum quum id novum atque antea inusitatum Germaniæ inferretur interpretati sunt ob similitudinem quandam

Cluverii Germania Antiq. L. III. Cap. 44.

Inde hodie fortasse vitrum glassum appellant nam succinum vitream habet perspicuitatem.

Salmas. Comm. in Solin. p. 165.

† Consent quidam *gleffum* nihil aliud esse quam quod Anglo Saxones *glar* Galli, Germani & Angli *glase* vocant.

Du Cange Gloss Vox *Gleffum*.

|| Certe *Ηλεκτρον* mentio apud Homerum non γαλου.

Salmas. Plin. Exerc. p. 773.

Homero & aliis antiquis nomen γαλας notum non fuisse sed pro eo *Ηλεκτρος* dici.

Budæi Lexicon Vox *Ηλεκτρον*.

glastum,* perhaps from the shining appearance it might give to their skins, or possibly because its ashes might be used in the making of glass. The Romans called the same plant by the name of *vitrum* †, the word they used to signify glass.

Galen makes mention of glass in A. D. 143. several parts of his works. ‡ He appears to be well acquainted with it, and the method of making it. He tells us, that it was made from sand melted in furnaces, which was required to be pure, since if any metallic substance was mixed therewith, the glass was spoiled. Those concerned in the manufacture, knew by looking at the sand if it was fit for this purpose. In other places, he advises medicines of a corrosive nature to be kept in glass vessels, as such are not liable to be corroded, or to impart any bad qualities. Glass was also used for cupping glasses in his time, much in the same way as at present.

* *Simile plantagini glastum in Gallia vocatur, quo Britannorum conjuges nurusque, toto corpore oblitæ, quibusdam in sacris & nudæ incedunt, Æthiopum colorem imitantes.*

Plin. Lib. XXII. Cap. 1.

† *Omnes vero se Britanni vitro inficiunt quod cæruleum efficit colorem,* Cæs. Bell. Gall. L. V.

‡ *De Simpl. Medicam. facultate. Lib. IX. De Terrâ Samiæ. De Antidotis. Lib. VIII. Cap. 8. De compos Pharm. secund. loc. L. VIII. Cap. 5.*

Apuleius

A. D. 161: Apuleius. Apuleius mentions the manufactory of glass cups in his time, as highly worked and carved in various ways, and of great value.

A. D. 214. Alexander Aphrodisiensis. Alexander Aphrodisiensis, a Greek writer, and a commentator on Aristotle, has several remarks on glass* relative both to its brittleness, especially on change of temperature, and its transparency.

The manufacturers of glass seem to have been erected into a kind of Company at Rome, and to have had a street assigned them, which was in the first region or division of the city, near the Porta Capena. †

A tax was laid upon them by A. D. 220. Alexander Severus, ‡ which subsisted in the time of Aurelian, || and probably long after.

The first author that I find, who makes mention of glass in windows, though there is no

* Αι υελοι εν τω χειμωνι θερμου σφοδρα τινος εμβληθοντος ερηγυνται. Alex. Aphrod. probl. I.

Ωσπερ δι υελου εμφανει το ευανδες του χειματος. Alex. Aphrod. ex. Steph. Thesaur. Græc. vox Υαλος.

† Sextus Rufus in descript. urb. Romæ.

‡ Ælii Lampr. Alex. Severus.

|| Vopiscus Aurelianus.

doubt it was in use for this purpose
 A. D. 320. pre, is Lactantius, * who speaks in
 Lactantius. in terms of glass being used as a
 transparent substance in windows, for
 which it appears to have been in common use
 together with the lapis specularis.

St. Jerome† likewise speaks of
 A. D. 422. glass windows formed of glass,
 Hieronymus melted and cast into thin plates,
 obiit. At. 91. being in use in his time.

Paulus Silentarius, ‡ a poet and
 A. D. 534. historian of the sixth century, who
 Paulus Silen- wrote in verse a description of the
 tarius. church of Sancta Sophia at Constan-
 tinople, speaks of the brightness of the sun's rays
 at its rise, coming through the eastern windows
 of that church, which were covered with glass.

* Manifestius est mentem esse quæ per oculos ea quæ sunt
 opposita transpiciat, quasi per fenestras lucenti vitro aut
 speculari lapide obductas.

Lactant De Opific Dei. Cap. 5.

† Vitrearum fenestrarum mentio apud Hieronymum quæ
 vitro in tenues laminas fuso obductæ erant.

Salm. Plin. Exerc. p. 771.

‡ ————— δοχεια φωτος ανοιγει
 Λεπταλαις νελοις κεκαλυμμενα, των δια μεσσης,
 Φαιδρον αιανσεαπτουρα φαισφορος ερχεται ηως.

Gregory

A. D. 571
Gregory of
Tours.

Gregory of Tours^{*} describing the ravages of war, makes frequent mention of the devastations committed on the windows of the churches.

A. D. 571.
Fortunatus.

Fortunatus[†] likewise, who was contemporary with Gregory of Tours, and also bishop of Tours and Poitiers, wrote a poem on the church at Paris, where he describes the light coming through the glass windows, as one of the principal circumstances that contributed to its beauty and ornament.

A. D. 630.
Johannes
Philoponus.

Johannes Philoponus[‡] the philosopher, who lived according to Helvicus, about the year 630, but according to Hoffman, a century earlier, not only speaks of glass, but of the panes being fastened in with plaister, much in the same way as at present.

* Ascendentes per eum, effracta vitrea ingressi sunt.

Gregor. Turon. Lib. VI. C. 10.

Effractis cellulæ vitreis hastas per parietis fenestras injiciunt. Ibid. L. VII. C. 29.

Si aliud inquit invenire non possum vel has ipsas quas cerno vitreas auferam. Lib. I. Miracul. C. 29.

† Prima capit radios vitreis oculata fenestris,
Atificisq. manu clausit in arce diem.

Fortunatus. Lib. II. Poem 11. De Eccles. Parisiac.

‡ Λαμπτήρας νομει η τα υελια α δια της γυψηπλα σλικης τεκης επιτιθειται ταις οικιας χαριν του φωτιζεσθαι ταυτας. Phil. 11.
post Analecta citat a Salm. Plin. Exerciet, 771.

St. Audoen the bishop of Rouen, A. D. 651. in his history of the life of his contemporary St. Eligius, the bishop of Noyon, * mentions a miraculous appearance in form of an arch or bow, about the great glass windows of a certain church.

The venerable Bede † relates also, A. D. incert. that about the middle of this century, the art of making glass was brought into England by Benedict an Ecclesiastic, the minister of Ofway, the king of Northumberland.

Thomas Stubbs, however, in his account of the prelates that have succeeded to the See of York, says, A. D. 726. Wigfred bishop of Worcester. that Wigfrid, bishop of Worcester, ‡ brought first into Britain the art of making glass windows, which is inconsistent with what is related by Bede.

Leo Ostiensis || speaks of the windows in his time being made with glass plates fixed in lead, and fastened A. D. 760. Leo Ostiensis.

* Apparuit subito in pariete circa vitroam maximam veluti arcus in rotundo. Vita Sancti Eligii. Lib. II. Cap. 45.

† Chronicon Ranulphi. Higdeni. Ed. Gale. Vol. I. p. 235.

‡ Vide etiam Bedam de Wiremuthense monasterio. L. I. C. 5. de vitreis fenestris.

|| Fenestras plumbo simul ac vitro compactis tabulis ferreque connexis inclusit. Leo. Ost. L. III.. C 27.

together

together with iron, much as we fee them at present.

A. D. 800.
Anastafius. Anastafius * an hiftorian of Rome, who was librarian to the Pope, mentions, that in the Pontificate of Leo III. who became Pope about the year 800, painted glafs in windows was in ufe. The fame writer describes four large glafs ornaments of the penfible kind, that were hung up in the church of St. Clement the martyr, weighing fifty pounds.

A. D. 1156. The ftatutes of the church of Tra- guier,† in Lower Britany, in the 12th century, fpeak of the windows of churches and chapels being ornamented with arms, and mili- tary enfigns, painted upon the glafs in them.

* Hoffm. Lexic. Vox Feneftra.

. Idem fecit prædictus præful in Ecclefia beati Clementis Martyris atque Pontificis, Regnum quod pendet fupra altare majus ex auro puriffimo fculptile fine gemmis habens in medio crucem de Auro cum gemmis fixis in eadem cruce. Vitreas quinque & quæ pendent item Vitreas numero qua- tuor penfantes libras quinquaginta.

Anaft. in Vitâ Leonis IV.

† Qui feneftras ecclefiarum & capellarum dictarum noftrarum civitates & diocefis aliquando devotione aliquando ambitione & fuperbia vitrare & vitris hujus modi arma & figna depingi faciunt prætenduntque per appofitionem & picturam armorum & fignorum hujus modi vitra memorata, &c. Stat. Ecclef. Trecur. A. D. 1156.

A. D. 1156. Sugerius * abbot of St. Denys, the minister of Lewis VII. speaks of a glass window being presented to the church at Paris, by Barbedaurus the dean, that cost fifteen pounds, which is upwards of 47 pounds sterling intrinsic value, exclusive of the alteration occasioned by the present relative plenty of money.

A. D. 1309. It appears from a charter in the beginning of the fourteenth century, that a glass cup was then valued at a denarius, † or about threepence halfpenny sterling, intrinsic value, exclusive of the alteration in the relative value respecting the present time.

A. D. 1338. † A short time afterwards, there appears a charter of stipulation for the erection of a glass-house, to be kept up constantly and worked.

* Obiit Barbedaurus Decanus & Sacerdos qui fecit fieri vitream quindecim libris comparatam.

Suger Lib. De Admir. sua. Cap. 29.

† Item a quolibet verrerio exponente vitros suos ad vendendum levatur unus vitrus vel unus denarius quod verrierius maluerit. Du Cange Vox Verreries.

† Pactis infra scriptis videlicet quod infra dictum nemo dictus Guionetus faciat domum fortem & ibidem debeat habitare & verreriam ibidem facere tenere & operari facere in ea perpetuo opus vitrorum sive vitrei.

Du Cange Vox Verreria.

In

A. D. 1364. * In the year 1364, there was a street in Paris, called from this manufactory.

† A charter of Richard II. of England, A. D. 1386. quoted by Rymer, about the same period, speaks of glass, and the manufactures of it for windows.

* *Transfulerunt domino dicto regi unam domum sitam Parisii in vico vitreria.* Du Cange *Vox Vitreria.*

† Cum quædam capella reparanda existat ac de vitro & vitriatoribus pro reparatione fenestrarum & aliorum locorum ejusdem capellæ multipliciter indigeat.

Rymer's *Fæd.* Tom. VII. p 527.

On the DIFFERENT QUANTITIES of RAIN which FALL, at DIFFERENT HEIGHTS, over the same SPOT of GROUND, with a LETTER from BENJAMIN FRANKLIN, LL. D. By THOMAS PERCIVAL, M. D. &c. Read January 21, 1784.

IT is a reflection which may mortify pride and humble arrogance, but ought certainly to animate the spirit of patient attention, and console us under the disappointments of philosophical pursuits, that many of the most interesting laws of nature have remained undiscovered, till some happy coincidence of circumstances hath pointed them out to inquiry or observation. Thus the energy of fire must have been known and felt from the creation of the world; but the regularity of the expansile power, on different bodies, is a modern discovery, of uncertain date. And the real nature of this subtile element, which pervades and actuates all matter, and is continually perceptible to our senses, is yet but imperfectly explored. The ancients were acquainted with the magnifying power of *dense mediums*; and Seneca has noticed, that small letters appear larger and brighter when viewed through a glass globe filled with water. He has remarked, also, that apples are more beautiful,

beautiful, when swimming in such a vessel. But these observations, which must have been made by numberless spectators, in a long succession of years, were regarded as solitary facts; and it was not till the thirteenth century, that spectacles were constructed, in consequence, probably, of the experiments made by the Arabian philosopher Alhazen, and our justly celebrated countryman Roger Bacon. Yet though magnifying glasses came then into general use, and must have been daily handled by artists and others, three hundred years elapsed before it occurred to any one to put them together, so as to form a telescope. The collection of watery vapours in the air, the figures of clouds, and the descent of rain, could pass in no age unnoticed by mankind, and have long been the subjects of attentive investigation. Yet it is a very recent discovery, which we owe to the sagacity of a most ingenious physician and philosopher, that a manifest difference subsists in the quantity of rain which falls, at different heights, over the same spot of ground.

A comparison having been made between the rain which fell in two places, in London, about a mile distant, it was found that the quantity in one of them constantly exceeded that in the other, not only every month, but almost every time it rained. The apparatus used was very exact; and this unexpected variation did not
appear

appear to be owing to any mistake, but to be the regular effect of some cause, hitherto unnoticed. The rain-gage, in one of these places, was fixed above all the neighbouring chimnies; the other was considerably below them: and there was reason to suspect, that the difference in the quantity of rain, might be owing to the different situations of the vessels, in which it was received. A funnel was, therefore, placed above the highest chimnies, and another upon the ground of the garden, belonging to the same house; and the like diversity was found between the two, thus near together, which had subsisted, when they were fixed, at correspondent heights, in different parts of the town. Similar experiments were made on Westminster Abbey;* and repeated at Bath, Liverpool, Middlewich, and other places, with nearly uniform results. The observations, therefore, however new and singular, are too well authenticated, to admit of the least degree of doubt: and it is the office of philosophy to furnish an adequate and rational solution of them. Dr. Heberden conjectures that the phenomenon depends on some *unknown* property of electricity. To me it appears probable that the common laws, by which this power influences the ascent and suspension of vapours, are sufficient to explain their precipitation in rain, and

* Phil. Transact. vol. LIX. p. 359.

the lately discovered mode of its descent. And in a Memoir,* written some time ago, I endeavoured to prove, that the electrical fluid is strongly attracted by water; and that by destroying the cohesion between its particles, and repelling them from each other, it becomes a powerful agent in evaporation, and in the formation of clouds. Thus when two clouds, containing different portions of electric fire, come within the sphere of mutual attraction, they will rush together, and the electrical fluid, being diffused through a larger space, the particles of water will unite, and forming themselves into drops, a shower will be produced: that as the rain descends, through an atmosphere containing little electric fire, it will be continually communicating it; the drops will coalesce more and more together, by the progressive diminution of the power which counteracts their mutual attraction; and consequently, in a given space, a much larger quantity will fall near to, than at a distance from the surface of the earth. And, lastly, that to this effect the precipitation of the vapours, contained in a dissolved or diffused state, in the lower regions of the atmosphere will, in some degree, contribute: for it has been observed to be fair, upon the top of the Cathedral

* See the author's Philosophical, Medical and Experimental Essays, vol. III. p. 112.

at York, at the time when there were small drizzling rains, with thick mists, in the streets below.*

The Memoir, of which I have here given a brief view, was distributed amongst my literary correspondents, and procured me many curious and interesting observations on the subject. And, I trust, my friend Dr. Franklin will forgive the liberty I take, in communicating, to the society, the following letter, with which I was honoured by him, on this occasion. The opinions and conjectures of so eminent a philosopher may, almost, be deemed common property; and on the point in question, they are of peculiar value and authority.

*Extract of a Letter from BENJAMIN FRANKLIN,
L.L.D. &c. to Dr. PERCIVAL.*

“ ON my return to London I found your favour, of the sixteenth of May (1771). I wish I could, as you desire, give you a better explanation of the phænomenon in question, since you seem not quite satisfied with your own; but I think we want more and a greater variety of experiments in different circumstances, to enable us to form a thoroughly satisfactory hypothesis.

* Hunter's Georgical Essays, p. 112.

Not that I make the least doubt of the facts already related, as I know both Lord Charles Cavendish, and Dr. Heberden to be very accurate experimenters: but I wish to know the event of the trials proposed in your six queries; and also, whether in the same place where the lower vessel receives nearly twice the quantity of water that is received by the upper, a third vessel placed at half the height will receive a quantity proportionable. I will however endeavour to explain to you what occurred to me, when I first heard of the fact.

I suppose, it will be generally allowed, on a little consideration of the subject, that scarce any drop of water was, when it began to fall from the clouds, of a magnitude equal to that it has acquired, when it arrives at the earth; the same of the several pieces of hail; because they are often so large and weighty, that we cannot conceive a possibility of their being suspended in the air, and remaining at rest there, for any time, how small soever; nor do we conceive any means of forming them so large, before they set out to fall. It seems then, that each beginning drop, and particle of hail, receives continual addition in its progress downwards. This may be several ways: by the union of numbers in their course, so that what was at first only a descending mist, becomes a shower; or by each particle in its descent through air that contains
a great

a great quantity of dissolved water, striking against, attaching to itself, and carrying down with it, such particles of that dissolved water, as happen to be in its way; or attracting to itself such as do not lie directly in its course, by its different state with regard either to common or electric fire; or by all these causes united.

In the first case, by the uniting of numbers, larger drops might be made, but the quantity falling in the same space would be the same at all heights; unless, as you mention, the whole should be contracted in falling, the lines described by all the drops converging, so that what set out to fall from a cloud of many thousand acres, should reach the earth in perhaps a third of that extent, of which I somewhat doubt. In the other cases we have two experiments.

1. A dry glass bottle, filled with very cold water, in a warm day, will presently collect from the seemingly dry air that surrounds it, a quantity of water that shall cover its surface and run down its sides, which perhaps is done by the power wherewith the cold water attracts the fluid, common fire that had been united with the dissolved water in the air, and drawing that fire through the glass into itself, leaves the water on the outside.

2. An electrified body left in a room for some time, will be more covered with dust than other bodies in the same room not electrified,
which

which dust seems to be attracted from the circumambient air.

Now we know that the rain, even in our hottest days, comes from a very cold region. Its falling sometimes in the form of ice, shews this clearly; and perhaps even the rain is snow or ice when it first moves downwards, though thawed in falling: and we know that the drops of rain are often electrified: but those causes of addition to each drop of water, or piece of hail, one would think could not long continue to produce the same effect; since the air, through which the drops fall, must soon be stript of its previously dissolved water, so as to be no longer capable of augmenting them. Indeed very heavy showers, of either, are never of long continuance; but moderate rains often continue so long as to puzzle this hypothesis: So that upon the whole I think, as I intimated before, that we are yet hardly ripe for making one."

SPECULATIONS *on the* PERCEPTIVE POWER *of*
 VEGETABLES. *By* THOMAS PERCIVAL, M. D.
 F. R. S. &c. &c. *Read February 18, 1784.*

- - - These are not idle, philosophic dreams;
 Full Nature *seems* with life. - - -

THOMSON'S Spring, Second Edit. line 136.*

IN all our enquiries into truth, whether natural or moral, it is necessary to take into previous consideration, the kind of evidence which the subject admits of; and the degree of it, which is sufficient to afford satisfaction to the mind. Demonstrative evidence is absolute, and without gradation; but probable evidence ascends, by regular steps, from the lowest presumption, to the highest moral certainty. A single presumption is, indeed, of little weight; but a series of such imperfect proofs may produce the fullest conviction. The strength of belief, however, may often be greater, than is proportionate to the force and number of these proofs, either individually or collectively considered. For, as uncertainty is always painful to the understanding, very slight evidence, if the subject

* These lines are omitted in the subsequent editions of Thomson's Seasons.

be capable of no other, sometimes amounts to credibility. This every philosopher experiences, in his researches into nature; and the observation may serve as an apology for the following *jeu d'esprit*; in which I shall attempt to shew, by the several analogies of organization, life, instinct, spontaneity, and self-motion, that plants, like animals, are endued with the powers, both of perception and enjoyment.

I. Vegetables bear so near a similitude to animals in their STRUCTURE, that botanists have derived from anatomy and physiology, almost all the terms employed in the description of them. A tree or shrub, they inform us, consists of a cuticle, cutis, and cellular membrane; of vessels variously disposed, and adapted to the transmission of different fluids; and of a ligneous, or bony substance, covering and defending a pith or marrow. Such organization evidently belongs not to inanimate matter; and when we observe, in vegetables, that it is connected with, or instrumental to the powers of growth, of self-preservation, of motion, and of seminal increase, we cannot hesitate to ascribe to them a LIVING PRINCIPLE. And by admitting this attribute, we advance a step higher in the analogy we are pursuing. For, the idea of life naturally implies some degree of perceptivity: And wherever perception resides, a greater or

K 2

less

less capacity for enjoyment seems to be its necessary adjunct. Indefinite and low, therefore, as this capacity may be, in each single herb or tree, yet, when we consider the amazing extent of the vegetable kingdom, "from the cedar of Lebanon to the hyssop upon the wall," the aggregate of happiness, produced by it, will be found to exceed our most enlarged conceptions. It is prejudice only, which restrains or suppresses the delightful emotions, resulting from the belief of such a diffusion of good. And, because the framers of systems have invented arrangements and divisions of the works of God, to aid the mind in the pursuits of science, we implicitly admit as reality, what is merely artificial; and adopt distinctions, without proof of any essential difference. *Lapides crescunt; vegetabilia crescunt et vivunt; animalia crescunt, vivunt, et sentiunt.* This climax, of Linnæus, is conformable to the doctrines of Aristotle, Pliny, Jungius, and others: But none of these great men have adduced sufficient evidence, to support the negative characteristics, if I may so express myself, on which the three kingdoms of nature are here established. That a gradation subsists, in the scale of beings, is clearly manifest; but the higher advances we make in physical knowledge, the nearer will the degrees be seen to approach each other. And it is no very extravagant conjecture to suppose, that, in some future period, perceptivity may

may be discovered to extend, even beyond the limits now assigned to vegetable life. Corallines, madrepores, millepores, and sponges were formerly considered as fossil bodies: but the experiments of Count Marfigli evinced, that they are endued with life, and led him to class them with the maritime plants. And the observations of Ellis, Jussieu and Peysonel, have since raised them to the rank of animals.* The detection of error, in long established opinions concerning one branch of natural knowledge, justifies the suspicion of its existence in others, which are nearly allied to it: And it will appear, from the prosecution of our enquiry into the instincts, spontaneity, and self-moving power of vegetables, that the suspicion is not without foundation.

II. INSTINCT is a propensity, or movement to seek, without deliberation, what is agreeable to the particular nature, actuated by it; and to avoid what is incongruous or hurtful. It is a practical power, which requires no previous knowledge or experience; and which pursues a present or future good, without any definite ideas or foresight; and often, with very faint degrees of consciousness. The calf, when it first comes into the world, applies to the teats of the cow, utterly ignorant of the taste, or nutritious quality of the milk, and consequently,

* Consult *Philos. Transact. Amœnitat. Academic.* and Bishop Watson on the Subjects of Chemistry.

with no views, either to sensual gratification, or support: And the duckling, which has been hatched under a hen, at a distance from water, discovers a constant restlessness and impatience; and is observed to practise all the motions of swimming, though a stranger to its future designation, and to the element, for which its oily feathers, and web-like feet, are formed. Instincts analogous to these, operate with equal energy, on the vegetable tribe. A seed contains a *germ*, or plant in miniature, and a *radicle*, or little root, intended by nature to supply it with nourishment. If the seed be sown in an inverted position, still each part pursues its proper direction. The *plumula* turns upward, and the *radicle* strikes downward, into the ground. A hop-plant, turning round a pole, follows the course of the sun, from south to west, and soon dies, when forced into an opposite line of motion: But remove the obstacle, and the plant will quickly return to its ordinary position. The branches of a honey suckle shoot out longitudinally, till they become unable to bear their own weight; and then strengthen themselves, by changing their form into a spiral: When they meet with other living branches, of the same kind, they coalesce, for mutual support, and one spiral turns to the right, and the other to the left; thus seeking, by an instinctive impulse, some body on which to climb, and increasing the
the

the probability of finding one, by the diversity of their course: For if the auxiliary branch be dead, the other uniformly winds itself round, from the right to the left.*

These examples, of the instinctive œconomy of vegetables, have been purposely taken from subjects, familiar to our daily observation. But the plants of warmer climates, were we sufficiently acquainted with them, would probably furnish better illustrations of this acknowledged power of animality: And I shall briefly recite the history of a very curious exotic, which has been delivered to us from good authority; and confirmed by the observations of several European botanists.

The *Dionæa Muscipula* is a native of North Carolina. Its leaves are numerous, inclining to bend downwards, and placed in a circular order: they are jointed, and succulent: The upper joint consists of two lobes, each of which is semi-oval in its form, with a margin furnished with stiff hairs; which embrace each other, when they close from any irritation. The surfaces of these lobes are covered with small red glands, which probably secrete some sweet liquor, tempting to the taste, but fatal to the lives of insects: For, the moment the poor animal alights upon these parts, the two lobes rise up,

* Lord Kaimes's Gentleman Farmer.

grasp it forcibly, lock the rows of spines together, and squeeze it to death: And, lest the struggles for life should disengage the insect, thus entangled, three small spines are fixed amongst the glands, near the middle of each lobe, which effectually put an end to all its efforts: nor do the lobes open again, while the dead animal continues there. The dissolution of its substance, therefore, is supposed, by naturalists, to constitute part of the nourishment of the plant. But as the discriminative power of instinct is always limited, and proceeds with a blind uniformity when put into exertion, the plant closes its leaves as forcibly, if stimulated by a straw or a pin, as by the body of an insect: Nor does it expand them again, till the extraneous substance is withdrawn.*

III. If the facts and observations, which have been adduced, furnish any presumptive proof of the instinctive power of vegetables, it will necessarily follow, that they must be endued with some degree of SPONTANEITY. For the impulse to discriminate and to prefer, is an actual exertion of that principle, however obscure the consciousness or the feeling may be, with which it is accompanied: And such volition presupposes an innate perception, both of what is consonant, and of what is injurious to the constitution of the individual, or species directed by it. But

* See the Annual Register for 1775, p. 93.

it is the design of this little Essay, rather to investigate nature, than to appeal to metaphysical considerations: I shall proceed, therefore, to point out a few of those phenomena, in the vegetable kingdom, which indicate spontaneity.

Several years ago, whilst engaged in a course of experiments to ascertain the influence of fixed air on vegetation, the following fact repeatedly occurred to me. A sprig of mint, suspended by the root, with the head downwards, in the middle glass vessel of Dr. Nooth's machine, continued to thrive vigorously, without any other pabulum, than what was supplied by the stream of mephitic gas, to which it was exposed. In twenty-four hours, the stem formed into a curve, the head became erect, and gradually ascended towards the mouth of the vessel; thus producing, by successive efforts, a new and unusual configuration of its parts. Such exertions in the sprig of mint, to rectify its inverted position, and to remove from a foreign, to its natural element, seems to evince volition to avoid what was evil, and to recover what had been experienced to be good. If a plant, in a garden-pot, be placed in a room, which has no light, except from a hole in the wall, it will shoot towards the hole, pass through it into the open air, and then vegetate upwards, in its proper direction. Lord Kaimes relates, that, " amongst the ruins of New Abbey, formerly a
" monastery

“ monastery in Galloway, there grows on the
 “ top of a wall, a plane tree, twenty feet high.
 “ Straitened for nourishment, in that barren
 “ situation, it several years ago directed roots
 “ down the side of the wall, till they reached
 “ the ground, ten feet below : And now, the
 “ nourishment it afforded to these roots, during
 “ the time of descending, is amply repaid ; hav-
 “ ing every year, since that time, made vigorous
 “ shoots. From the top of the wall, to the sur-
 “ face of the earth, these roots have not thrown
 “ out a single fibre, but are now united into a
 “ pretty thick hard root.”*

The regular movements, by which the sun-
 flower presents its splendid disk to the sun, have
 been known to naturalists, and celebrated by
 poets, both of ancient and modern times. Ovid
 founds upon it a beautiful story ; and Thomson
 describes it as an attachment of love, to the ce-
 lestial luminary.

“ But one, the lofty follower of the sun,
 “ Sad when he sets ; shuts up her yellow leaves,
 “ Drooping all night ; and when he warm returns,
 “ Points her enamour'd bosom to his ray.”

Summer, line 216.

IV. Nature has wisely proportioned the
 POWERS OF MOTION, to the diversified necessities
 of the beings endued with them. Corallines
 and Seapens are fixed to a spot, because all their

* Gentleman Farmer.

wants may be there supplied. The oyſter, during the afflux of the tide, opens to admit the water, lying with the hollow ſhell downwards: But when the ebb commences, it turns on the other ſide; thus providing, by an inconfiderable movement, for the reception of its proper nutriment; and afterwards diſcharging what is ſuperfluous.* Mr. Miller, in his late account of the iſland of Sumatra, mentions a ſpecies of coral, which the inhabitants have miſtaken for a plant, and have denominated it Lalan—Cout, or ſea-graſs. It is found in ſhallow bays, where it appears like a ſtraight ſtick, but when touched, withdraws itſelf into the ſand.† Now, if ſelf-moving faculties, like theſe, indicate animality, can ſuch a diſtinction be denied to vegetables, poſſeſſed of them in an equal, or ſuperior degree? The water-lily, be the pond deep or ſhallow in which it grows, puſhes up its flower-ſtems, till they reach the open air, that the farina fecundans may perform, without injury, its proper office. About ſeven in the morning, the ſtalk erects itſelf, and the flowers riſe above the ſurface of the water: In this ſtate they continue till four in the afternoon, when the ſtalk becomes relaxed, and the flowers ſink and cloſe. The motions of the ſenſitive plant have been long

* Sprat's *History of the Royal Society*.

† *Philoph. Tranſact.* vol. LXVIII. p. 178.

noticed with admiration, as exhibiting the most obvious signs of perceptivity. And if we admit such motions, as criteria of a like power, in other beings, to attribute them, in this instance, to mere mechanism, actuated solely by external impulse, is to deviate from the soundest rule of philosophizing, which directs us not to multiply causes, when the effects appear to be the same. Neither will the laws of electricity better solve the phenomena of this animated vegetable: For its leaves are equally affected by the contact of electric, and non-electric bodies; shew no change in their sensibility, whether the atmosphere be dry or moist; and instantly close when the vapour of volatile alkali, or the fumes of burning sulphur are applied to them. The powers of chemical stimuli, to produce contractions in the fibres of this plant, may perhaps lead some philosophers, to refer them to the *vis insita*, or irritability, which they assign to certain parts of organized matter, totally distinct from, and independent of, any sentient energy. But the hypothesis is evidently a solecism, and refutes itself. For the presence of irritability can only be proved by the experience of irritations, and the idea of irritation involves in it that of feeling.

But there is a species of the order of Decandria, which constantly and uniformly exerts a self-moving power, uninfluenced either by chemical stimuli, or by any external impulse whatsoever.

This

This curious shrub, which was unknown to Linnæus, is a native of the East Indies, but has been cultivated in several botanical gardens here. I had an opportunity of examining it, in the collection of the late Dr. Brown. It is trifolious, grows to the height of four feet, and produces, in autumn, yellow flowers. The lateral leaves are smaller than those at the extremity of the stalk; and all day long, they are continually moving either upwards, downwards, or in the segment of a circle: The last motion is performed by the twisting of the foot stalks; and whilst one leaf is rising, its associate is generally descending: The motion downwards is quicker and more irregular, than the motion upwards, which is steady and uniform. These movements are observable, during the space of twenty-four hours, in the leaves of a branch lopped off from the shrub, and kept in water. If, from any obstacle, the motion be retarded, upon the removal of that obstacle, it is resumed with a greater degree of velocity.* I cannot better comment on this wonderful degree of vegetable animation, than in the words of Cicero. *Inanimatum est omne quod pulsu agitatur externo; quod autem est animal, id motu cietur interiore et suo.*

I have thus attempted, with the brevity prescribed by the laws of this Society, to extend

* See Encyclopædia Britannica, Art. Hedyfarum.

our views of animated nature; to gratify the mind with the contemplation of multiplied accessions to the general aggregate of felicity; and to exalt our conceptions of the wisdom, power, and beneficence of God. In an undertaking, never yet accomplished, disappointment can be no disgrace: In one, directed to such noble objects, the motives are a justification, independently of success. Truth, indeed, obliges me to acknowledge, that I review my speculations with much diffidence; and that, I dare not presume to expect they will produce any permanent conviction in others, because I experience an instability of opinion in myself. For to use the language of Tully, *Nescio quomodo, dum lego assentior; cum posui librum, assensio omnis illa elabitur*.—But this scepticism is perhaps to be ascribed to the influence of habitual preconceptions, rather than to a deficiency of reasonable proof. For besides the various arguments which have been advanced, in favour of vegetable perceptivity, it may be further urged, that the hypothesis recommends itself, by its consonance to those higher analogies of nature, which lead us to conclude, that the greatest possible sum of happiness exists in the universe. The bottom of the ocean is overspread with plants, of the most luxuriant magnitude. Immense regions of the earth are covered with perennial forests. Nor are the Alpes, or the Andes, destitute of herbage,

though

though buried in depths of snow. And can it be imagined, that such profusion of life subsists without the least sensation or enjoyment? Let us, rather, with humble reverence, suppose, that vegetables participate, in some low degree, of the common allotment of vitality: And that our great Creator hath apportioned good, to all living things, in number, weight, and measure."*

SUPPLEMENT to the foregoing PAPER; containing further Observations on the SENSITIVE PLANT.

IN the speculations, concerning the perceptive power of vegetables, which were read before this Society last spring, I observed, that the motions of the sensitive plant are not to be explained by the laws of electricity. For its leaves are alike affected by the contact of electric and non-electric bodies; shew the same sensibility whe-

* It has been estimated, that our globe contains 20,000 species of vegetables; 3000 of worms; 12,000 of insects; 200 of amphibious animals; 2600 of fishes; 550 of birds; and 200 of quadrupedes. (Vid. Linn. Amœnit. Academ. and Stillingfleet's Miscellaneous Tracts, p. 125). A calculation like this, it is evident, must be very defective; because founded on past discoveries in a science, which is now in a state of rapid progression. But future accessions, both of plants and animals, with respect to number, may produce no material changes in their relative proportions.

ther the atmosphere be dry or moist; and instantly close when certain chemical stimuli, such as the vapour of vol. alkali, or the fumes of burning sulphur, are applied to them. These conclusions were founded on the recollection of experiments which I made more than twenty years ago. But the Abbè Barthalon de St. Lazane, in a late treatise on the electricity of vegetables, has adopted an opposite hypothesis, and adduced the following trials in support of it. When the sensitive plant, says he, is touched with a piece of polished metal, terminated at each end by a round knob, its leaves shrink back and shut. When it is touched with a piece of glass, of the same form, it remains insensible. But if this piece of glass be electrified, and the plant be touched with it in this state, the leaves instantly close themselves. Hence he infers, that the plants called *Mimosæ* are endued with a much greater portion of electrical fluid than others; that this fluid escapes when touched by a foreign body, capable of conveying it away; and that they shrink by being thus deprived of what is essential to their health and vigour.*

I have lately procured a sensitive plant, with the design of repeating the Abbè's experiments.

* See Abbè Barthalon de St. Lazane *D'Electricité des Vegetaux*: Also Appendix to Monthly Review, vol. XVII. P. 135.

But at the present season of the year, I find this vegetable in a very languid state; so that my trials have not afforded me much satisfaction. I could not, however, perceive any difference, whether the leaves were touched with a piece of polished iron, or a stick of sealing wax. And the following well authenticated facts, seem to refute the Abbè's hypothesis, concerning the electrical œconomy of this plant.

I. The branches of the sensitive plant have two motions, the one natural, the other artificial. By the first it progressively increases, in the morning, the angle which it forms with the stem; and retreats in the same gradual manner, in the afternoon. By the second it contracts its leaves, when forcibly touched or shaken.

II. The sensibility of the plant seems, chiefly, to reside in the articulation of the branches of the common foot stalk, or of the particular foot stalk of each wing.

III. No motion ensues from cautiously piercing the branch with a needle, or other sharp instrument.

IV. A stroke, or an irritation, produces a more forcible effect, than an incision or even an entire section.

V. A slight irritation only acts upon the neighbouring parts, and extends its influence according to its force.

VI. Plunging the plant in water seems to have no other effect, than that of diminishing its vigour.

VII. A piece of wax, strongly electrified, made the leaves of the sensitive plant close quickly, by attracting them to it with considerable force.

VIII. The motions of the sensitive plant are owing to a strong contraction. Each foot stalk seems to be terminated with a kind of joint, on which the leaves turn, with surprizing facility.*

NOVEMBER 9, 1784.

* Consult Milnes's Botanical Dictionary; the Encyclopædia Britannica; and Whytt on Vital Motions.

An EXPERIMENTAL INQUIRY into the CAUSE of the PERMANENT COLOURS of OPAKE BODIES. By EDWARD HUSSEY DELAVAL, F. R. S. of the ROYAL SOCIETIES of UPSAL, and GOTTINGEN, of the INSTITUTE of BOLOGNA, and of the LITERARY and PHILOSOPHICAL SOCIETY of MANCHESTER. Communicated by Mr. Charles Taylor. Read May 19, 1784.

THE chief design of this inquiry is, to investigate the nature, origin, and cause, of the permanent colours of opaque bodies.

I was led to the pursuit of it, from a persuasion of its utility, to those interesting and elegant Arts, whose object is the preparation, and use, of colouring substances.

The discovery of this principle is the foundation, on which alone all the parts and materials of the knowledge, relative to those Arts, can be raised and supported.

It should be the office of experimental philosophy, to examine the powers and properties of all the materials, requisite to technical uses. Nor should its views be confined to the theories, which result from those researches, but directed to the practical application of them,

In proportion as the Principles of any Science are unknown or misconceived, the advancement of the Arts and Manufactures, which depend on them, must of course be impeded : for, without those guides, no addition or improvement can be attained, except such as arise from mere accidental observation.

But when scientific Principles are disclosed to the Artist, he becomes enabled to draw, from those original sources, an ample store of useful inventions, by which his Art is constantly enriched ; and from thence considerable advantages may be derived. And thus the speculative Sciences, by their extension to practical purposes, become objects of great public utility.

The truth of this observation is, in no instance, more conspicuous, than when applied to the Science of Optics, and to the Arts and Manufactures, which are connected with, and dependent upon it. For, the invention and improvement of the several operations, which owe their rise to that Science, appear to have kept an equal pace with the philosophical discoveries, by which they were suggested : and their progress seems to have been constantly retarded, in proportion as the correspondent branches of the parent Science have remained in a state of deficiency or imperfection.

The experiments and observations, which have been made by means of Transparent Colourless Substances,

Substances, are very numerous, and the action and powers of such bodies, in reflecting and refracting light, have been, in a great measure, discovered and explained.

In consequence of those discoveries, optical instruments have been brought to a considerable degree of perfection.

It is further observable, that from the misconception of a single circumstance, in this department of the science, there arose an obstacle to the construction of telescopes, which the united efforts of artificers were unable to surmount, till the error was rectified.

This error, which had escaped even the penetration of Sir Isaac Newton, originated from a supposition, that the divergency of all the rays, which pass through any media, is constantly equal to their refraction.

The inaccuracy of this opinion was first observed by M. Euler, and the subject was afterwards attentively pursued by the Academicians Clairaut, Klingenshierna, Beguelin, Zeiher, and D'Alembert: but, we are indebted to M. Dolland, for the final discovery of the Principles, and their application to the construction of telescopes, superior to any which had ever been before produced.

In this happy instance, the genius of the Philosopher, and the hand of the Artist, were united in the same person.

I have thus briefly considered the present state of our knowledge, of the optical properties of Colourless Transparent Substances; and the condition and progress of the Arts which are subordinate to, and connected with them.

The industry and attention of philosophers has not hitherto, in any great degree, been exercised on the consideration of Permanently Coloured Bodies.

It will appear, in the course of this inquiry, that the disposition of such substances to exhibit their colours, has not been examined by experiments, which are the true and only means of discovering, and explaining, its cause. And it will be shewn, that the hypothetical opinions, which have been offered on this subject, are not supported by actual observations, and do not account for, or agree with, the phænomena.

From the imperfection of this branch of Optics, and from the influence which its defects exert on those Arts, whose improvement depends upon a clear and just conception of the nature, preparation, and use of colouring materials, it is not difficult to deduce the reason of the immaturity, and deficiency, under which they labour.

So far, indeed, are we from having advanced towards a state of perfection, that if we cast our views back to the remotest regions of Science, we shall find, from such a retrospect, that the
most

most ancient nations possessed an excellence in all those Arts, which the ablest moderns cannot dispute with them.

In a former work, I have shewn that the Art of Dying was cultivated in the remotest ages, in Phœnicia, Egypt, India, the land of Canaan, and other countries; and that they excelled even in the most difficult and elaborate branches of this art. They were also skilled in making artificial gems, and tinging glass, and enamel, with the brightest colours.

From the testimony of the earliest historians, we are informed of the high antiquity of the Art of Painting, in Egypt, and other countries which gave birth to the Arts and Sciences: and many beautiful remains of antiquity, which are still extant, are clear and lasting proofs of the great proficiency of those ancient nations in that Art.

Theophrastus, Pliny, and others, have enumerated the colours, employed in the various methods of antique painting.

These colours include almost all the pigments, which are employed by the moderns. Prussian Blue, which, with a few others, has been added, was discovered by an accidental mixture of the ingredients, which enter into the composition of it. Nor is it so durable as the blue paints, which were in use before its introduction.

Pliny informs us, that in his time Painting had greatly degenerated from its former state.

It is not my purpose in this brief review of the colouring arts, to advert to their condition at that period, as they had then fallen from their primitive excellence; nor to consider them in any other respect, than that which regards the beauty, and durability, of the colours, abstracted from any other circumstances whatsoever.

The paints, which Apelles used, were so bright, that he found it expedient to glaze his pictures, with a dusky varnish, that the vividness of the colours might not offend the sight.*

But notwithstanding the allowed merit of this celebrated painter, and of his cotemporaries, in the execution of their art, their colours were greatly surpassed, in variety, brightness, and permanency, in the works which had been perfected long before such arts were cultivated in Greece; and which, after so long a series of ages, still continue unimpaired, and probably will ever remain so, unless destroyed by violence.

I have selected the following passages, relative to this subject, from the authentic description

* *Inventa ejus et cæteris profuere in arte. Unum imitari nemo potuit, quod absoluta opera atramento illinebat ita tenui, ut idipsum percussu claritates oculorum excitaret, custodiretque a pulvere et sordibus, ad manum intuenti demum appareret. Sed et tum ratione magna ne colorum claritas oculorum aciem offenderet, veluti per lapidem specularem intuentibus è longinquo.*

Plinii L. XXXV. Cap. 10.

which

which Norden has given of the extensive and magnificent remains of Thebes, in the Upper Egypt, which was the capital of the Eastern World. That traveller, in a letter to the Baron de Stofch, thus relates his observations.

“ I hope to get the author you tell me of, but
 “ as he treats only of the paintings upon the cases
 “ of the Mummies, he will be of no great use to
 “ me in explaining those wonderful ones, that
 “ I have seen upon an infinite number of ancient
 “ buildings, or in giving the least idea of them.
 “ Imagine to yourself, in the extent of an Italian
 “ league, palaces with columns thirty-two French
 “ feet in circumference, cased with sandy stones
 “ cut in squares, and all over covered, within
 “ and without, with paintings, representing the
 “ worship of the deities of the country, the
 “ ceremonies and customs of the inhabitants,
 “ their manner of making war and sailing,
 “ together with love devices intermixed. Con-
 “ sider likewise, that the manner of painting is
 “ so totally different from any thing in practice
 “ at this time, as to make it necessary for me
 “ to give you some slight idea of it. A painting
 “ eighty feet high, and proportionably broad,
 “ is divided into two ranges of gigantic figures
 “ in bass relief, and covered with most exquisite
 “ colours, suited to the drapery and naked parts
 “ of the figure. But what is still more wonder-
 “ ful is this, that the *azure, the yellow, the green,*
 “ and

“ *and the other colours made use of, are as well*
 “ *preserved, as if they had been laid on but yesterday,*
 “ *and so strongly fixed to the stone, that I was never*
 “ *able to separate them in the least degree. You*
 “ *will ask me, whether the design is good and*
 “ *has taste? yes, Sir, the whole is executed*
 “ *with much greater exactness, than the idols*
 “ *of granite which we both have seen in the*
 “ *Capitol.*”*

These further remarks are cited from the journal of the same author.† “ We passed
 “ afterwards

* Norden's Travels in Egypt, by Templeman, p. 33.

† Ib. vol. II. p. 75.

In confirmation, and as a farther explanation of these accounts, I shall here insert some extracts from Perry's voyage to Upper Egypt, which abounds in descriptions and praises of the paintings, that adorn the temples and palaces of that splendid scene of antiquity.

|| “ At Carnac (commonly called Luxor il Kadim, and
 “ formerly a part of Thebes) we went ashore, and marching
 “ along, with great avidity directly to it, we found the
 “ most stately, magnificent and surprizing temple that ever
 “ eye beheld: doubtless, it is impossible to think, speak, or
 “ write of this edifice, without transport or rapture; for its
 “ splendour, glory, and magnificence are such, as are truly
 “ unspeakable, and perhaps inconceivable. The front of this
 “ portal from top to bottom, on each side for a width of nine
 “ or ten feet, and the whole inner side of the portal the same,
 “ are all filled with the most beautiful figures in basso relievo,
 “ and

|| A View of the Levant, by C. Perry, M. D. London. 1743. p. 341.

“ afterwards to the ruins, that are found on the
“ north side. There is no doubt but they are
“ the remains of the palace of Memnon.

“ The reader may there remark, letter C the
“ portico of a temple, capable of giving a great
“ idea of the Egyptian architecture.

“ The hieroglyphics are agreeable to the
“ sight, and when you are quite near, *their co-*
“ *lours have a charming effect.*

“ It is something surprising to see how gold,
“ *ultra marine, and divers other colours, have pre-*
“ *served their lustre to the present age.*”

“ and hieroglyphics, and all these are *painted over in a most*
“ *curious and exquisite manner.*

“ This grand sumptuous portal, is no other than a pas-
“ sage which leads from the first court or salon, into a se-
“ cond. This salon, which is equimensurate with the for-
“ mer, viz. one hundred paces wide, and sixty deep, is per-
“ fectly crowded with pillars, like the former as to shape and
“ ornaments, only that these are larger, being near twelve
“ feet in diameter, and seventy-two feet high: all these co-
“ lumns as well as the ceiling, roof and walls of the apart-
“ ment are quite covered or crowded with figures in basso
“ relievo, and hieroglyphics, *all exquisitely beautiful, and*
“ *finely painted all over—and which may seem very extraor-*
“ *dinary, all these things look as fresh, splendid and glorious,*
“ *after so many ages, as if they were but just finished.*”

Diodorus Siculus, in his description of Thebes, mentions
such gigantic figures, covered with the most beautiful co-
lours, as well as the other kinds of paintings, which are still
extant in the remains of that city.

Such

Such was the state of Painting in Egypt, above three thousand years ago. The other colouring arts were carried to a high degree of improvement, at an equally remote period.

We learn, from the concurrent testimony of both sacred and profane historians, that the countries, where these Arts originally flourished were antecedent, and superior to all others, in their diligent and successful observations of nature, and in the invention and culture of the Sciences.

These, undoubtedly, gave rise to the executive Arts, and opened a way to their advancement and perfection.

But, after a succession of several ages, both the theoretical knowledge, and the practical skill, of those nations, underwent a considerable decline, and shared the general desolation which had befallen, from civil disasters, and foreign invasions.

Those repositories of the Arts and Sciences had already far receded from their primeval condition, at the time that the ancient sages of Greece resorted to them, for instruction.

So that, although the researches of those travellers were repaid by the acquirement of some general physical truths, which had been traditionally preserved, they could not, by the most diligent inquiry, attain an insight into any of the progressive means of information, from which such truths had been deduced.

Nor

Nor were they enabled, on their return to their own country, to transfer to it the methods of executing those beautiful and magnificent works, which had been the objects of their admiration.

The moderns were not furnished with any adequate means of retrieving the Principles of ancient Science, till they began to avail themselves of experimental observations; and till academies were instituted, for the purpose of enabling them mutually to communicate their discoveries to each other.

The present age has produced many excellent philosophers, whose labours have been directed to inquiries, from whence great improvements must necessarily result to the Arts, and Operations, which are of the highest importance to the convenience and happiness of mankind.

I shall think myself fortunate, if the slight addition of my endeavours prove, in the least degree, conducive to that end.

In a former work, I have considered the Differences or Changes of Colour, in permanently coloured bodies, and have shewn that they are effected in the same manner, and according to the same law, which prevails in Transparent Colourless Substances.

By this means, the philosophical principle is established, and applied to the practical uses of several Arts: particularly to those of Dying, Painting,

ing, and such others as depend upon the knowledge, and management, of Colouring Materials.

The experiments, by which the cause of those changes of colours was investigated, consisted chiefly of various methods of uniting the Colouring Particles into larger, or dividing them into smaller, masses.

I shall now proceed to examine those properties of Permanently Coloured Substances, by which they operate on the rays of light, in producing colours.

No essential information, relative to this subject, can be obtained from any optical writers, who preceded Sir Isaac Newton. For, the origin and nature of light and colours were entirely unknown, till they were unfolded by his researches.

To him we owe the discovery of the different refrangibility of the rays of light; the invariable colours of the differently refrangible rays; the power of thin transparent plates, particles, and fibres, to exhibit several colours, according to their several thicknesses and densities; as well as the investigation and explanation of several other properties of light.

All these were results of experiments made by means of Transparent Colourless Media. But, he does not appear to have examined, with equal attention and success, the properties of Permanently Coloured Bodies, and their operations on
the

the rays of light. And indeed, from the state and extent of his researches, it was not possible that he could have attained to a clear insight into that part of Optics, as he was not furnished with any regular series of experiments, which could be applied to the solution of its phenomena.

As the progress of Sir Isaac Newton's discoveries did not extend beyond the limits of his experiments, it may be fairly concluded, that, without such sources of information, the most acute and penetrative understandings must fail of success in physical inquiries.

This great philosopher, however, in the few passages wherein he treats of Coloured Substances, constantly avows his defect of experiments. It is probable that, by this candid acknowledgment, he intended that the opinions which he had expressed, on this subject, which are merely conjectural or founded on abstract speculation, might be distinguished from those clear truths, which he had deduced from his numerous and accurate experiments, performed with Transparent Colourless Bodies.

Thus, having mentioned some of those substances, which transmit one sort of light and reflect another sort, he makes this remark: " If these liquors or glasses were so thick and massy, that no light could get through them, I question not but they would, like all other opaque bodies,

“ bodies, appear of one and the same colour,
 “ in all positions of the eye, though this I cannot
 “ yet affirm by experience.” *

And he thus expresses himself, relative to the opacity of glass wedges filled with red, and blue liquors, when viewed conjointly. “ This Mr. Hook tried casually with glass wedges filled with red and blue liquors, and was surprized at the unexpected event, the reason of it being then unknown; which makes me trust the more to his experiment, though I have not tried it myself.” †

We find, at the close of the Optics, a passage relative to the inflections of the rays of light and the colours made thereby, which seems capable of being extended to all those observations, which the illustrious author had left imperfect, or had not prosecuted with that eminent degree of industry and circumspection, which are generally conspicuous in his inquiries. It is as follows: “ When I made the foregoing observations, I designed to repeat most of them with more care and exactness; but I was then interrupted, and cannot now think of taking these into farther consideration.” ‡

Sir Isaac Newton was of opinion, that *all Coloured Matter reflects* the rays of light, some

* Newton. Opt. L. I. Part. II. Prop. X. Probl. V.

† Ib.

‡ Ib. L. III. ad calc.

bodies reflecting the more refrangible, others the less refrangible rays, more copiously. And that “this is not only a true reason of these colours, but even the only reason.”*

He conceived that opaque bodies reflect the coloured light from their anterior surface, by some power of the body evenly diffused all over its surface, and external to it.

He thus delivers his doctrine relative to transparent coloured liquors:† “A transparent body “which looks of any colour by transmitted light, “may also look of the same colour by reflected “light, the light of that colour being reflected “by the farther surface of the body, or by the “air beyond it. And then the reflected colour “will be diminished, and perhaps cease, by “making the body very thick, and pitching it “on the back side to diminish the reflection of “its farther surface, so that the light reflected “from the tinging particles may predominate. “In such cases, the colour of the reflected light “will be apt to vary from that of the light “transmitted.”

As these opinions are merely hypothetical, and are not supported by the evidence of any experiments, I judged it expedient carefully to inquire into the phænomena of Coloured Substances,

* Ib. L. I. Par. II. Prop. X. Probl. V.

† Ib.

from which alone any clear illustration of such questions can be attained.

For this purpose, I entered upon a series of experiments, which have been performed with Transparent Coloured Liquors, and Glasses, as well as with opaque, and semitransparent bodies.

I shall, in the first place, consider Transparent Coloured Substances; because they are of the simplest kind, as they consist only of the Colouring Particles united with, and diffused throughout, Transparent Media, such as spirit of wine, oil, water, or glass.

From the examination of such tinged media, I have been enabled to discover several properties of Coloured Matter, which are very different from those, which have hitherto been thought to prevail.

For instance, it will appear from the experiments which I shall relate in the sequel, that in Transparent Coloured Substances, the Colouring Matter *does not reflect any light*; and when by intercepting the light which was transmitted, it is hindered from passing through such substances, they do not vary from their former colour,* to any other colour, but become entirely *black*.

As

* Optical writers generally use the word *colour* in an equivocal sense: sometimes expressing thereby the primary colours, as opposed to whiteness: at other times including whiteness also. I have, throughout this inquiry, used this word

As the incapacity of the Colouring Particles of Transparent Bodies to reflect light, is deduced from experiments which are very numerous, and whose results are constant and invariable, it may be held as a general law, at least till some exception to it can be discovered.

This law will appear still more extensive, if it be considered that, for the most part, the tinging Particles of liquors, or other Transparent Substances, are extracted from Opaque Bodies; that the Opaque Bodies owe their colours to those particles in like manner as the Transparent Substances do, and that by the loss of them, they are deprived of their colours.

By experiments made with several Opaque Bodies, it will be shewn that they actually do not exhibit their colours, by reflecting the rays of light. And, by the same experiments, the means, by which they do produce their colours, will be hereafter explained.

For the purpose of observing the manner in which Transparent Coloured Liquors act upon the

word to express only the *primary colours*, or such a mixture of them, as does not compose whiteness, or any of the gradations between white and black; such as are called by Sir Isaac Newton, grey, dun, or russet brown.

rays of light, I procured small vials of flint glass, whose form is a parallelepiped; the height of these, exclusive of the neck, is about two inches, and the base about one inch square; their necks are cylindrical, and are about two inches in length.

I covered the bottom, and three of the sides of each of these vials, with a black varnish; the cylindrical neck, A, and the anterior side, B, except at its edges, were left uncovered.

I carefully avoided leaving any crevices in the varnish, that no light might be admitted, except through the neck, or the anterior side, of the vials.

In these experiments, both the inner and exterior surfaces of the glass must be perfectly clean; and those liquors, which are apt to deposit a sediment on the bottom or sides of the vessels which contain them, must be put into the vials, only when the examination of them is intended: those, which are not subject



to this inconvenience, may be constantly kept in the vials.

The uncovered side of the vial should not be placed opposite to the window, through which the light is admitted; because in that situation the light would be reflected from the farther side of the vial, and would be transmitted through the coloured liquor; and it is observable that smooth black surfaces reflect light very powerfully. Now as it is a principal object in the experiment that no light be transmitted through the liquors, this will be accomplished by placing the uncovered side of the vial in such a direction, that it may form a right angle with the window.

I have examined a great variety of Transparent Coloured Liquors, in vials, prepared and disposed as I have here described, and have constantly found that in every instance, that part of the liquor, which was contained in the neck of the vials, exhibited its colour distinctly and vividly; but, that portion, which was in the body of the vials, and which was viewed through the uncovered side, *exhibited no colour*, but was *black*.

From amongst numerous similar observations, I have selected those which are set down in the following table: I have not attempted therein to produce any regular or systematical collection of coloured liquors, but only to exhibit such specimens as may serve to shew the action of

vegetable, mineral, and animal colouring particles, on the rays of light.

The expressions, *reflected light*, and *transmitted light*, have been generally used, when Transparent Coloured Bodies have been considered. But, as the following experiments and observations, shew that Transparent Coloured Bodies are not endued with any *reflective* power, the word *reflected*, cannot properly be applied to the light which falls on them. I have, therefore, at the head of the last column of this table, substituted the words "*incident light*," instead of the usual expression, *reflected light*.

TABLE of TRANSPARENT COLOURED LIQUORS *viewed*
by TRANSMITTED, and by INCIDENT LIGHT.

LIQUORS.	By Transmitted Light.	By Incident Light.
1. Iron dissolved in the Nitrous Acid	Yellow	Black
2. Martial Alkaline Tincture of Stahl	Orange	Black
5. Vitriol of Iron dissolved in Water	Green	Black
4. Dilute Solution of Green Vitriol, with Infusion of Galls - - -	Blue	Black
5. Dilute Solution of Green Vitriol in Spirit of Wine, with Tincture of Galls in Spirit of Wine - - -	Blue	Black
6. Saturated Solution of Fixed Alkali, in which a small Quantity of Green Vi- triol is dissolved, with Infusion of Galls - - - - -	Red	Black
7. Dilute		

LIQUORS.

	By Transmitted Light.	By Incident Light.
7. Dilute Solution of Green Vitriol, with Phlogisticated Alcaline Lixivium	Blue	Black
8. Spa, and Pyrmont, Waters, with Infu- sion of Galls - - - -	Purple	Black
9. Solution of Vitriol of Copper -	Blue	Black
10. Copper dissolved in Nitrous Acid	Blue	Black
11. Crystals of Verdegris, dissolved in Distilled Vinegar - - -	Blue <i>Green*</i>	Black
12. Copper dissolved in Volatile Alkali	Blue	Black
13. Manganese fused with Nitre, or with Fixed Alkali, dissolved in cold Water	Green	Black
14. Manganese, thus prepared, dissolved in hot Water - - - -	Purple	Black
15. Cobalt dissolved in Nitrous Acid	Red	Black
16. Marine Acid, to which a small quan- tity of Nitrous Solution of Cobalt is added - - - -	Green	Black
17. Sympathetic Ink of Cobalt -	Red	Black
18. Solution of Gold - - - -	Yellow	Black
19. Dilute Solution of Gold, with Solu- tion of Tin - - - -	Red	Black
20. Solution of Platina - - - -	Orange	Black

* The names of the colours, which are printed in *Italic characters*, express those to which the principal colours, contained in the table, incline.

LIQUORS.

	By Transmitted Light.	By Incident Light.
21. Red Flowers, infused in Spirit of Wine, slightly acidulated with Nitrous Acid - - -	Red	Black
22. Red Flowers infused in Water, slightly acidulated with Nitrous Acid	Red	Black
23. Purple, and Blue Flowers, infused in Water, slightly acidulated with Nitrous Acid - - -	Red	Black
24. Purple, and Blue Flowers, infused in Spirit of Wine, slightly acidulated with Nitrous Acid - -	Red	Black
25. The same Red Infusions, with the addition of small quantities of Solution of Fixed Alkali - - -	Purple Blue Green	Black
26. Yellow Flowers infused in Distilled Water - - -	Yellow	Black
27. Yellow Flowers infused in Spirit of Wine - - -	Yellow	Black
28. Green Colouring Matter of Grass, and other Green Leaves, dissolved in Spirit of Wine - -	Green Yellow Red	Black
29. Prepared Turnsol infused in Water	Purple	Black
30. Juice of Black Currants - -	Red	Black
31. Black Cherries, Black Currants, and other Black Fruits and Berries, infused in Spirit of Wine -	Red	Black
32. Raspberries, and other Red Berries, infused in Spirit of Wine -	Red	Black

L I Q U O R S.

	By Transmitted Light.	By Incident Light.
33. Spanish Annatto dissolved in Spirit of Wine - - - - -	Yellow	Black
34. Spanish Annatto dissolved in Caustic Vegetable Fixed Alkali - -	Yellow	Black
35. French Berries infused in Spirit of Wine - - - - -	Yellow	Black
36. French Berries infused in Distilled Water - - - - -	Yellow	Black
37. Sap Green infused in Spirit of Wine	Green	Black
38. Sap Green infused in Distilled Water	Green Yellow Red	Black
39. Indigo dissolved in Oil of Vitriol, and afterward diluted with Water	Blue	Black
40. Indigo dissolved in Caustic Vegetable Fixed Alkali - - - - -	Green	Black
41. Litmas infused in Distilled Water	Red Purple Blue	Black
42. Prepared Archil, Water - -	Purple	Black
43. Prepared Archil, Spirit of Wine	Purple	Black
44. Gamboge dissolved in Spirit of Wine	Yellow	Black
45. Dragon's Blood dissolved in Spirit of Wine - - - - -	Orange	Black
46. Weld infused in Distilled Water	Yellow	Black
47. Madder infused in Spirit of Wine	Orange	Black
48. Alaknet infused in Spirit of Wine	Red	Black
49. Alkanet infused in Oil of Turpentine	Red	Black
50. Alkanet		

LIQUORS.

	By Transmitted Light.	By Incident Light.
50. Alkanet infused in Expressed Oils	Red	Black
51. Fustic infused in Distilled Water	Yellow	Black
52. Fustic infused in Spirit of Wine	Yellow	Black
53. Turmeric infused in Spirit of Wine	Yellow	Black
54. Turmeric infused in Distilled Water	Yellow	Black
55. Logwood infused in Distilled Water	Yellow	Black
56. Logwood infused in Thames Water	Red	Black
57. Logwood infused in Spirit of Wine	Yellow	Black
58. Red Saunders infused in Spirit of Wine	Red Orange	Black
59. Cochineal infused in Distilled Water	Red	Black
60. Cochineal infused in Spirit of Wine	Red	Black
61. Kermes infused in Distilled Water	Yellow	Black
62. Kermes infused in Spirit of Wine	Yellow	Black
63. Ox Gall, diluted with Distilled Water	Yellow	Black
64. Blood with Spirit of Sal Ammoniac	Red	Black
65. Spirit of Nitre impregnated with Phlogiston - - - - -	Yellow	Black
66. The same with Distilled Water	Green	Black
67. Nitrous Spirit distilled from equal parts of Arsenic and Nitre -	Green	Black
68. The same with Distilled Water	Blue	Black

These

These experiments shew, that Transparent Coloured Liquors do not yield any colour by reflection, but by transmission only.

If these liquors are spread thin on any white ground, they appear of the same colours, which they had exhibited, when viewed in the necks of the vials; as the light reflected from the white ground is, in this case, transmitted through the coloured medium.

But when they are spread upon a black ground, they afford no colour. The black ground, however, should not be a polished body; as the light, reflected thereby, would be transmitted through the thin medium on its surface, and be tinged by passing through it.

I shall now proceed to relate some experiments, which were performed with tinged glasses; these being, in many respects, analogous to coloured liquors.

I made several parcels of colourless glass. That, which I principally employed in these experiments, consisted of equal parts of borax and white sand. The glass was reduced to powder, and afterwards ground, together with the ingredients by which the colours were imparted.

This method, of incorporating the tinging particles, is greatly preferable to mixing them with the raw materials. The glasses, thus composed, excel most others in hardness, and are scarcely inferior, in lustre, to real gems.

All the experiments, which have been made with *transparent coloured glasses*, shew that they appear vividly coloured, when they are of such a thinness, and are tinged so dilutely, that light is transmitted through them. But when they are in larger masses, and the tinging matter is more densely diffused through them, they are *black*. For, these as well as the *transparent coloured liquors* do not exhibit colours by *reflection*, but by *transmission* only.

I shall here instance some trials, which I made for the purpose of observing the proportions of tinging matter, which produce colour, or blackness.

I tinged glass green, by adding to it one sixtieth part of its weight of copper. It is indifferent whether the copper, used in this process, be calcined, or applied in its metallic state.

I made a blue glass, by the addition of zaffre, a purple glass by manganese, a red glass by gold, and yellow glasses by silver, and by calcined iron. I also made a yellow glass, similar to a topaz, by the admixture of a small quantity of pulverized charcoal: and the same colour was imparted by wheat flower, by rosin, and by several other inflammable matters.

From the masses of transparent coloured glass, which were thus composed, small pieces were separated, and ground by a lapidary, which resembled gems of their respective colours.

Having

Having formed pieces of such glasses, about two inches thick, I inclosed all their sides with black cloth, except at their farther, and anterior surfaces. Each of these pieces of glass vividly exhibited its colour, when viewed by transmitted light: but when the transmitted light was intercepted, by covering the farther surface, the anterior surface afforded no colour, but appeared *black*.

When plates of Transparent Coloured Glass, somewhat thicker than window glass, are viewed by transmitted light, it is well known, that they exhibit their several colours.

I intercepted the light, which was transmitted through such coloured plates, by fixing a piece of black cloth, contiguous to their farther surface. The plates, thus prepared, when placed in such a direction, that they form a right angle with the window, appear perfectly *black*.

From the phænomena, presented by such plates, two observations may be deduced. (1.) That the Colouring Particles do not reflect any light. (2.) That a medium, such as Sir Isaac Newton has described, is diffused over both the anterior, and farther surfaces of the plates, whereby objects are reflected equally, and regularly, as by a mirror.*

* Whenever it is said that light is reflected by the surface of any substance, it should be understood, from this expression, that the reflection is effected by the medium, diffused over its surface.

When

When a lighted candle is placed near one of these coloured plates, the flame is reflected by the medium, which is diffused over the anterior surface of the plate. The image, thus reflected, resembles the flame, in size, and colour. For, it is scarce sensibly diminished, and *it is not in the least tinged by the coloured glass.*

If the plate be not so intensely coloured, or so massy, as to hinder the transmission of the light of the candle, there appears a secondary image of the flame, which is reflected by the medium, contiguous to the farther surface of the glass. And as the light, thus reflected, passes back through the coloured glass, it is vividly tinged by it.

When the glass, used in this experiment is green, the secondary image of the flame assumes a bright green colour. When glasses of other colours are used, the colour of the secondary image is always the same, as that of the glass.

The secondary image is less, than that which is reflected from the anterior surface. This diminution is occasioned by the loss of that part of the light, which is absorbed, in passing through the coloured glass. For, whenever any medium transmits one sort of rays, more copiously than the rest, it stops a great part of the oppositely coloured rays. And much more light is lost, in its passage through coloured, than through pellucid colourless, substances.

In

In making these observations, it is proper to choose coloured plates of glass, which are not in every part of an equal thickness, that the secondary image may not be reflected in such a direction, as to coincide with, and be intercepted by, that which is reflected from the anterior surface.

When the plates are so thick, and so copiously coloured, that the light cannot penetrate to their farther surface, they appear intensely *black*, in whatever direction they are viewed, and they do not afford any secondary image; but only reflect from their anterior surface, the flame, or any other objects which are opposed to them. These objects are represented in their own proper colours, and are as free from any tinge, or adventitious colour, as those which are reflected from looking glasses, or specula made of white metals.

It is manifest from hence, that the colouring particles have no share in effecting this reflection. For, if they possessed any reflective power, whence is it that glasses, copiously stored with colouring matter, impart no colours to the images, which they reflect?

It appears, from these observations, that transparent coloured bodies, as well in a solid, as in a fluid, state, exhibit colours by transmission only, but do not reflect any colour.

The order of this inquiry leads me, in the next place, to the consideration of the Colouring Particles, *pure, and unmixed with other media.*

For

For the purpose of procuring masses made up of such particles, I reduced several Transparent Coloured Liquors to a solid consistence, by evaporation. When a gentle heat is employed in this operation, the Colouring Matter, which is thus concentrated, remains unimpaired, and capable of again imparting its colour unaltered, to other liquors.

In this state, the Colouring Particles *reflect no colour*, and, as no light is transmitted through them, they are *black*.

Amongst the liquors, which I evaporated, were the tinctures, and infusions, of the colouring particles of red, purple, blue, and yellow flowers, of logwood, brazil, fustic, turmeric, red saunders, alkanet, sap green, kermes, and all the other Transparent Coloured Liquors, enumerated in the preceding table, which are capable of being reduced to a solid consistence, without undergoing such changes, during their evaporation, as render them opaque.

The opacity, which some liquors are apt to acquire from the loss of part of their solvents, arises from various causes, such as the crystallization of saline matters, or the coalescence of the colouring particles, into masses which differ considerably, in density, from the menstrua in which they were dissolved.

The consideration of this subject is of much importance to the art of dying. I have constantly

stantly observed, that whenever colouring particles become opaque, their size renders them incapable of entering the pores of wool, silk, cotton, or linen, or of cohering to their surface. For, the attractive force, by which particles tend mutually to each other, and cohere, is weakened, in proportion as their bulk increases, so that the degree of magnitude of the colouring particles, which is essential to the opacity of liquors, is inconsistent with the minuteness, requisite to those means of union, by which dying is effected.

I shall select one instance, from amongst many which are applicable to these observations. I infused, in a pint of distilled water, such a quantity of fustic, that the water was saturated with its colouring particles. The aqueous part of this infusion was evaporated by a gentle, but continued, heat, till it was reduced to a solid mass.

The liquor, during every part of this process, continued transparent, and the solid extract, which it yielded, transmitted a yellow colour, when spread thin, but appeared *black*, when thicker masses were viewed.

Having prepared another pint of the same infusion, I evaporated half of the water, and left the remainder, till it was cold. In this state it became turbid, and opaque. When this liquor was filtered, a transparent infusion passed through the filter, and an opaque fecula was retained by

the filter, which was afterward dried, and appeared to be a white powder, slightly tinged with yellow. This powder did not cohere to the filtering paper, but was easily separable from it. It was again soluble in water, and formed with it a liquor, in all respects, similar to the original infusion.

From these circumstances, it appears that a given proportion of water, or a sufficient degree of heat, is requisite to the solution of the colouring particles of fustic. And experience evinces that those particles, which are too gross to pass through filtering paper, are incapable of entering the pores, or firmly cohering to the surface of bodies.

Many dying ingredients, such as the colouring particles of logwood, kermes, and various other matters, are soluble in water, in all proportions, and therefore their infusions are not subject to become turbid, or opaque, during their evaporation. And the solid extracts, obtained from these liquors, reflect no colour, but are *black*.

I also formed solid masses, by mixing with a small quantity of drying oil, pigments, which consist chiefly of colouring matter, unmixed with opaque ingredients, such as indigo, Prussian blue, and sap green. These paints exhibit their respective colours, when thin plates of them are viewed by transmitted light; but appear entirely
black,

black, when the transmitted light is intercepted, or when the masses are of a sufficient thickness.

Several fruits and berries, as black cherries, black currants, blackberries, and many others, afford instances of blackness arising from the dense state of the colouring matter. Their juices are red, when spread thin on a white ground, or otherwise viewed by transmitted light.

Thus it appears, from all the preceding experiments and observations, that Transparent Coloured Matter, whether diffused through colourless pellucid media, or condensed into solid masses, separate and unmixed, is not endued with any reflective power.

I shall proceed to consider the action, and properties, of the colouring particles of *opake* coloured bodies, and the means by which their colours are produced.

The transparent liquors and glasses, which have been already examined, owe their colours to such particles extracted from opake substances: and it has been shewn that those particles do not act upon light by reflection.

It has also been observed, that when coloured particles are spread thin upon any white ground, they exhibit their several colours, by transmitting the light reflected from the white ground.

I shall endeavour to prove, by several experiments and observations, that the colours of opake bodies are produced by a similar operation.

Amongst the natural bodies, which are the objects of this inquiry, vegetables claim our principal attention, from the great variety and brightness of their colours.

In order to examine the leaves, fruits, flowers, wood, and roots of plants, I found it necessary to separate their component parts, on which their colours depend.

The following experiments, made with this view, have enabled me to discover the cause of those colours, and the manner in which they are produced.

I digested, in rectified spirits of wine, grass and other *green* leaves of plants: by this means a transparent green tincture was obtained, which consisted of the colouring matter, dissolved by the spirit. I filled one of the vials, (No. 28.) with this liquor, and viewing that part of it which was in the neck of the vial, I observed that it *transmitted* a vivid green colour; but the other part of the tincture, which was contiguous to the uncovered side of the vial, reflected no light, and consequently appeared *black*.

I poured, into a white china cup, a small quantity of this tincture, which, by its presence, imparted to the bottom of the cup a green colour, exactly resembling that of the leaves from which the matter had been extracted.

After the Colouring Matter had been taken from the leaves, the leaves remained apparently
unaltered

unaltered in texture, and in every other respect, except in their loss of colour.

In this state, they consist principally of the fibrous and vascular parts, and are either perfectly *white*, or have their *whiteness* slightly tinged with brown.

I digested also in rectified spirit of wine, red, purple and blue flowers. All these yielded, to the spirit, their colouring matter, and by the deprivation of it appeared *white*. From most of these flowers, the spirituous menstruum acquired either no colour, or only a faint tinge. But, when it was acidulated, it became red, and, by the addition of an alkali, assumed purple, blue, and green, colours. In each of these states, the coloured tinctures were examined in the vials, as in (No. 21, 24, 25.) and, also were poured upon a white ground. All of them, by these means, were found to yield bright colours by transmission, but none of them reflected any light.

I also digested red, purple and blue flowers, in water slightly acidulated with nitrous acid, and thus obtained from them red infusions, which I have been able to preserve many years, without the least alteration in their colour, by saturating them with sea-salt. (No. 22, 23.)

By the addition of very small portions of alkali, these red liquors also were changed to purple, blue, and green. All these coloured infusions

were viewed, in the same manner as the preceding liquors, and were found to yield vivid colours by *transmission*, but to *reflect no colours*, (No. 25.)

The addition of the alkali must be very gradual: for if too much is added, at once, to the red liquor, the intermediate colours, between the red and the green, will be wanting. To half an ounce of the red infusion, it is proper to add, at once, only the least quantity of a solution of pearl ash, that can be taken up, upon the point of a pen, repeating this addition, slowly till each of the colours are produced.

The flowers, after having been repeatedly macerated in acidulated water, lost their colouring matter, and became *white*.

Yellow flowers also communicated their colours to water, and to spirit of wine. The infusions and tinctures of these flowers were subjected to the same experiments, as had been employed in the examination of the liquors already mentioned, and appeared yellow by *transmitted* light, but *did not reflect any colour*. (No. 26, 27.)

White paper, and linen, may be tinged, by dipping them in the infusions of the flowers of each colour: and by spreading, upon those *white* grounds, the expressed juices of such flowers, their colours may be communicated to the paper, and the linen.

These

These means of tinging are somewhat similar to the application of vegetable dyes to linen, and of transparent water colours to paper, many of which consist of the Colouring Matter of plants, such as indigo, litmus, sap green, gamboge, the vegetable lakes, and various others.

These operations are so well known, and the methods of executing them are so obvious, that I should not here have noticed them, if they had not led me to some observations respecting the *white* grounds, on which the colours are applied.

The consideration of those *white* substances affords much insight, into the manner in which the natural colours of vegetables are produced.

I have already shewn that, when the Colouring Matter of plants is extracted from them, the solid fibrous parts, thus divested of their covering, display that *whiteness*, which is their distinguishing character.

White paper, and linen, are formed of such fibrous vegetable matter; which is bleached, by dissolving and detaching the heterogeneous coloured particles.

When these are dyed, or painted, with vegetable colours, it is evident that they do not differ, in their manner of acting on the rays of light, from natural vegetable bodies: both yielding their colours by *transmitting* through the

Transparent Coloured Matter, the light which is reflected from the white ground.

For it appears, from the preceding experiments, that *no reflective power* resides in any of their component parts, except in their *white matter* only.

This white matter frequently exists, without any considerable mixture, in plants, while they are in a state of vegetation : as in cotton, white flowers, the pith, wood, seeds, roots, and other parts, of several kinds of vegetables.

When decayed trees, and other plants, have been long exposed to the weather, after they have ceased to derive nourishment from the earth ; their coloured juices are apt to be exhausted by the action of the rain, air, and sun ; by which means the remaining substance becomes perfectly bleached.

The *white matter* of all vegetables is composed principally of an earth. Their ashes consist of this earth, separated from the inflammable, and evaporable parts, to which they owed their colours.

I have rendered ashes intensely white, by carefully calcining them ; and afterwards grinding them with a small proportion of nitre, and exposing this mixture to such a degree of heat, as caused the nitre to deflagrate with the small particles of coal which remained unburnt ; and lastly, by dissolving, in marine acid, the
ferruginous

ferruginous matter diffused through them, and repeatedly washing the remaining ashes in a sufficient quantity of water.

By mixing ashes, thus purified, with glass, together with an additional portion of borax, I obtained an opake enamel remarkable for its whiteness.

From all these premises it appears, that the earth, which forms the solid substance of plants is *white*; that it is separable from the colouring matter by several means; that, whenever it is either pure and unmixed, or diffused through transparent colourless media, it exhibits its *whiteness*; and is the only vegetable matter which is endued with a reflective power.

I have hitherto described several cases, in which the *white matter of plants* may be brought to view, by the removal of the coloured particles which covered it. Its exposure may also be effected by other means.

It is well known that the vapour of burning sulphur whitens red roses. This effect is generally attributed to the vitriolic acid arising from the sulphur. But such an explanation is certainly erroneous, because the vitriolic acid, applied to the roses thus whitened, restores their red colour.

As sulphur is composed only of phlogiston and vitriolic acid, and as the whiteness is not caused by the acid, it is evident that it is effected by the phlogiston.

I exposed

I exposed several sorts of red, and purple flowers to the phlogiston, disengaged from hepar sulphuris decomposed by an acid, and to other phlogistic vapours, all of which whitened the flowers. I restored the red colour of each of these, by applying to them indiscriminately either vegetable, or mineral, acids.

It appears, from these experiments, that the colouring matter of the flowers is not discharged or removed, but only dissolved, by the phlogiston; and thereby divided into particles too minute to exhibit any colour. In this state, together with the vegetable juice in which they are diffused, they form a colourless transparent covering, through which the *white matter* of the flowers is seen untinged,

The Colouring Particles of plants consist principally of inflammable matter; and their solubility in phlogiston, and union with it, are analagous to the mutual action, which other inflammable bodies exert on each other. Thus, æther dissolves all essential, and expressed oils, animal empyreumatic oils, and resins. Sulphur, camphire, and almost all substances abounding in phlogiston, are soluble in oils, ardent spirits, or other inflammable menstrua.

The manner, in which the red colour of the flowers is restored, appears to me to be explicable from known chemical laws. When acids are applied to the whitened flowers, by their strong
affinity

affinity with the phlogiston which the sulphur had communicated, they unite with that principle, and disengage it from the colouring particles; which, being thus extricated, resume their original magnitude, and colour.

Fixed alcali, whose affinity also with phlogiston is very great, changes the whitened flowers to purple, blue, and green, which colours alcali always produces in such flowers.

The matter of light acts upon coloured bodies, in the same manner as the phlogistic vapours, whose operations have been here explained. Thus dyed silk, or other stuffs, exposed to the sun's light, are deprived of their colour, in every part, which lies in the direction of the rays, whilst those parts preserve their colour, which are defended from the access of the rays by their folds, or by the intervention of any opaque body which intercepts the light.

The colours, thus impaired by the action of phlogiston or of light, may be restored by the means already described, if they are applied whilst the solution of the colouring particles is recent: but, afterward they are apt to fly off, and be entirely dissipated, on account of the volatility, which the inflammable principle constantly imparts to matter, with which it is united.

The action and properties of phlogiston, and of the sun's light, are so exactly similar, that the identity

identity of those subtle principles can scarcely be doubted.

White metallic calces, such as the magistery of bismuth, and the crystals and solutions of silver, mercury, and lead, are turned black by the inflammable principle, which they acquire from the sun's light, as well as from phlogistic vapours. And calcined ferruginous earths, which do not obey the magnet, become subject to its attraction, after they have been impregnated with phlogiston, by light collected in the focus of a burning glass.

It is certain that vegetables receive, from the rays of light, all that store of inflammable matter with which they are so richly supplied.

This principle cannot be furnished by the earth, as the small quantity of it, which the soil contains, is inadequate to the effect: and even this small portion is produced from the decomposition of vegetables, or animals which have derived their nourishment from vegetables. Plants which, during their growth, are excluded from the solar light, abound in aqueous juices, but are deficient in oils, and other phlogistic products: and the privation of their other qualities, such as odour, taste, and colour, shews that the matter of light is essential to the vigour and perfection of vegetable substances.

Sir Isaac Newton was of opinion that "Gross
" bodies and light are convertible into one ano-
" ther, and that bodies receive much of their
" activity

“ activity from the particles of light which enter
“ their composition.”

He observes that “ Bodies and light act mu-
“ tually upon one another, that is to say, bodies
“ upon light in emitting, reflecting, refracting
“ and inflecting it, and light upon bodies by
“ heating them, and putting their parts into a
“ vibrating motion wherein heat consists.”* And
that the mutual action between light and inflam-
mable bodies is much stronger, than between
light and other bodies.

In classing several kinds of bodies, according
to their refractive powers, he instances “ Selenite,
“ rock crystal, island crystal, vulgar glass, and
“ glass of antimony, which are terrestrial stony
“ concretes.”† To these substances which consist
principally of earth, and have the weakest refrac-
tive powers, he thus opposes the following inflam-
mable substances ; “ The refraction of camphire,
“ oil olive, linseed oil, spirit of turpentine and
“ amber, which are fat,‡ sulphureous, unctuous
“ bodies, *and a diamond, which probably is an*
“ *unctuous substance coagulated*, have their refrac-
“ tive powers in proportion to one another as

* Newton. Opt. Qu. ad Calc.

† Ib. L. II. Part. III. Prop. X.

‡ Sir Isaac Newton, according to the custom of his time,
uses the word sulphureous, unctuous, &c. to signify what
later chymical writers express by the terms phlogistic or
inflammable.

“ their

“ their densities without any considerable variation. But the refractive powers of these untuous substances, are two or three times greater, in respect of their densities, than the refractive powers of the former substances in respect of theirs.”

The clear conceptions which Sir Isaac Newton had formed, respecting the refractive power of the inflammable principle, afford an instance of unparalleled penetration and discernment.

Diamonds, from their apparent resemblance to crystalline vitrifiable stones, and gems, were universally held, by naturalists and lapidaries, not to have differed in their constituent matter, from such stones and gems, except in a greater degree of purity.

Sir Isaac Newton, judging of diamonds by their refractive power, classes them with inflammable bodies, and as they are endued with the strongest refractive power, he does not scruple to rank them at the head of the inflammable bodies, as consisting of the purest phlogiston.

This remarkable observation has not, I believe, ever been noticed, by philosophers, or naturalists, as an object of their consideration: doubtless, because they were prejudiced by the apparent qualities of diamonds, and their resemblance to those of other gems, which seem to have withheld their attention from the powers and properties, the discovery of which was drawn from the more certain test of optical investigation.

After

After Sir Isaac Newton had published his Optical Works, almost a century had passed, during which no experiments were made, whereby the constituent matter of diamonds could be ascertained. Several eminent chymists, and philosophers, in France, have recently applied great skill and industry in the examination of that subject.

From their inquiries, it appears that diamonds, when enveloped in powdered charcoal, and inclosed in crucibles carefully luted, resist the force of fire, and remain unaltered, in the same manner as charcoal, and other solid inflammable bodies.

When exposed, under a receiver, to the focus of a large burning glass, they impart phlogiston to the air which is contained in the receiver.

When placed, under a muffle, upon a cupel or stand of white calcined refractory earth, in a degree of heat sufficient to melt pure silver, the diamonds send forth a continued flame, and thus entirely burn away.

When exposed to the fire, in thick vessels of white porcelain, perfectly closed with stopples of the same substance, so that their cavities contain only air and the inclosed diamonds, they are entirely dissipated, and disappear, without leaving the least trace of the matter, of which they were formed.

These experiments prove, that diamonds consist of phlogiston; and they are the only natural substance,

stance, in which that principle appears to exist pure and unmixed. For all inflammable liquors contain water: and all solid inflammable bodies leave a residuum of ashes, or coal, accordingly as they are burnt in open, or in close vessels.

Nor can any constituent parts of bodies pass through solid substances, except only phlogiston, and light. And from their agreement in this respect, the identity of these subtile principles is farther confirmed.

From the native form, and constituent matter of diamonds, may they not be properly defined *crystallized phlogiston*?

The chemical experiments, respecting the inflammable nature of diamonds, carry with them the greater clearness and conviction, as the philosophers, who made them, were entirely unprejudiced in their inquiries on that subject: for they do not seem to have been aware that Sir Isaac Newton had discovered, from optical observation, the same truth to which they were led by the chymical phænomena.

The solvent power of phlogiston, whether obtained from terrestrial bodies, or proceeding immediately from the light of the sun, is manifest in various instances similar to those which have been hitherto explained.

Silk is whitened by the phlogistic vapours of sulphur: and this operation does not appear to differ

differ from the change effected in flowers by the same vapour.

The light of the sun is found to be a necessary, and essential, agent in bleaching linen, bees' wax, and various other substances. Some part of the colouring matter, which impairs the whiteness of such bodies, not yielding to the power of any other solvent.

Red flowers are whitened by the electric spark, of whose inflammable nature we cannot entertain the least doubt. For the spark itself is a bright flame, and it yields the same smell, which all other phlogistic matters impart.

The electric spark, in like manner changes the blue infusion of turnsol, to red. The effects which it produces on the turnsol, and on red flowers, do not differ from each other, except in degree only. For, when vegetable matter is dissolved, it is changed from blue, to red; and when it is farther dissolved, it is divided into particles too minute to exhibit any colour.

A due attention to the changes of colour, and other effects, arising from the solvent power of phlogiston, will afford much insight into several operations of the arts and manufactures; and will furnish an explanation of many appearances, which occur in chymistry, and physics, which cannot otherwise be rightly understood.

The perfection of the arts of dying, and bleaching, and of preparing and preserving painters' Vol. II. O colours,

colours, essentially depend on the knowledge of this subject.

Solutions effected by means of phlogiston, frequently are wrongly attributed to the operation of supposed acid menstrea: as several kinds of substances are capable of being dissolved indiscriminately, either by acids, or phlogiston.

For the purpose of distinguishing, in any instance, between the action of the acid solvents, and that of the inflammable menstrea, it is proper to examine the nature of the matter, by which either of those principles is furnished.

Fixed air is generally supposed to possess an acid quality, and several of its properties are ascribed to its acidity.

The change of colour, produced in vegetable juices by the electric spark, is adduced as a proof of the acidity of fixed air. But it has been already shewn that this effect does not arise from acid, but from phlogistic, matter.

The acid quality of fixed air is also generally inferred, from its power of dissolving iron. But, phlogiston also is a solvent of iron. Thus, a considerable portion of that metal is always dissolved and held in solution, by the phlogisticated alkaline lixivium, which consists of inflammable matter calcined with fixed alkali. M. Margraf has shewn that several other metals are soluble in this lixivium. Hence it is evident that the solubility of iron does not prove the acidity of the solvent, but may arise from the phlogiston contained in it.

Fixed

Fixed air, by its combination with alcalies, diminishes their causticity, and promotes their crystallization. These properties are also supposed to be communicated by an acid, imparted by fixed air.

But, this hypothesis does not agree with the effects, which are produced by the combination of acids with alcalies. For, neutral salts are formed by the addition of acids to alcalies. And as alcalies do not become neutral salts, by their union with fixed air, but are only changed thereby, from caustic and deliquescent, to mild alcalies, capable of crystallizing, it is evident that the alteration, which fixed air causes in them, does not result from the introduction of an acid.

We must, therefore, turn our views to the consideration of some other principle, by which these effects may be produced.

It appears from various chymical processes, that alcalies are rendered mild, and capable of crystallizing, in proportion as they are united to phlogiston. The phlogisticated alkaline lixivium, when saturated, is perfectly mild, and, by a slight evaporation, is reduced to a concrete crystalline mass, which does not deliquesce, or imbibe the least moisture from the air, and no longer retains any alkaline character or property.

M. Beaumé, by an elegant and ingenious experiment, has proved the presence of phlogiston in mild alcalies, and has shewn that their power

of crystallizing depends upon their union with that principle.

He heated, in a silver vessel, a lixivium of mild alkali, which imparted to the silver a covering, or coating, of inflammable matter, by which its surface was tarnished, and became black. The lixivium was several times poured out of the silver vessel, and after the surface of the silver had been freed from the tarnish, the lixivium was replaced in it, and again heated, by which the tarnish was renewed. This was repeated till the lixivium no longer communicated any stain to the silver.

The causticity of the lixivium increased, in proportion as it imparted its phlogiston to the surface of the silver, and, at the end of the process, the alkali became perfectly caustic, and incapable of crystallizing.

These instances, and many others which might be adduced, seem to prove that the change, which fixed air produces in caustic alkalies, is not effected by acid, but by phlogistic matter.

It is certain that the matter, communicated to lime by fixed air, is the very same which it imparts to alkalies. For it may be transferred, unchanged, from one of those substances, to the other; and, when united to either of them, still retains the same *qualities*. Therefore, if phlogiston renders alkalies mild, and effects their crystallization, the same principle also precipitates lime,
and,

and, in like manner, restores it to its state of mild calcareous earth.

The experiments and observations, on which Dr. Black has established his comprehensive and consistent theory, clearly prove, that lime is precipitated from lime water, by fixed air: but his views were not extended to an investigation of the particular matter, or quality, whereby fixed air operates that effect.

Lime which has been precipitated from lime water, and restored to the state of a mild calcareous earth, is again soluble by the addition of a larger proportion of fixed air. This solution is attributed to the acid quality of fixed air; and it has been considered as a strange and extraordinary circumstance, that accordingly as different proportions of it are applied, it should act as a precipitant, and a solvent, of the same substance.

The simplicity, which nature observes in all her operations, will not permit us to suppose, that fixed air is possessed of two different or opposite qualities, by one of which it precipitates, and by the other of which, it dissolves.

The precipitation of lime from lime water, and its resolution, are effected by an equable uniform action, exercised by one and the same simple principle, which is a constituent and essential part of fixed air. And, such a precipitation, and resolution, are not extraordinary or complex phenomena, as they have been esteemed, but are

analogous to the ordinary and constant effects, which arise from chymical affinities.

This may be exemplified, by any compound which assumes a concrete solid consistence, by its union with a given quantity of a fluid, and which, by the addition of a larger quantity of the same fluid, is reduced to a liquid state.

Thus, when a due proportion of water is added to iron, and vitriolic acid, a mutual attraction takes place between these three ingredients, by means of which they are united, and, by their combination, a concrete vitriol, or metallic salt, is formed. But, if a greater quantity of water be added to this concrete salt, as the mutual attraction, after this addition, subsists equably between the vitriolic salt and the whole mass of water, the acid and ferruginous particles are more minutely divided, and diffused uniformly throughout every part of the water. And thus, the solid concrete salt is resolved, and a vitriolic liquor is formed, in which the water predominates.

Lime strongly attracts and unites with inflammable substances, such as sulphur, camphire, and resins. Fixed air has a still greater affinity to lime. Because in all the grosser substances, the phlogiston is allayed by salt, earth, and other matters: but, in fixed air, it exists in a purer, and consequently, a more active state.

As alcalies are rendered mild, or caustic, by the presence, or absence, of the inflammable principle,

ciple, it can hardly be doubted that the difference between mild calcareous earth, and quicklime, is also occasioned by a communication, or deprivation, of the same principle.

The origin of fixed air, seems to prove its phlogistic nature. For all bodies, which yield it, afford also inflammable matter: but many of them do not yield any acid. Calcareous spar, magnesia, and alkaline salts, send forth fixed air, and all these substances, by the loss of it, are deprived of their inflammable contents: diamonds, exposed to the focus of a burning glass under a receiver, impart to the air, contained in it, a power of precipitating lime, from lime water, when it is agitated with it. But it does not appear that any acid can be derived from those bodies.

Some of the properties of fixed air are consistent with either the character of acid, or of phlogiston. Such are, its power of altering the colour of vegetable juices; its affinity to alkalies; and ready union with lime; its power of dissolving iron, which is instanced in all acids, and in the phlogisticated alkaline lixivium; the antiseptic quality prevails equally in acids, and in inflammable spirits; acids are disengaged from substances, which are decomposed by stronger acids, phlogiston is likewise expelled from bodies, which are dissolved in acids.

The qualities of acid, and phlogiston, agree in these, and in several other instances, but fixed air

is endued with properties, which are peculiar to phlogiston. Such as its power of effecting the crystallization of alcalies, without changing them to neutral salts; its tendency to escape from water, and its affinity with the air, by means of which a considerable quantity of fixed air is united with, and diffused throughout, every part of the atmosphere.

Water, as well as phlogiston, is a constituent part of all substances which yield fixed air. Both these principles have a strong affinity to air. This appears from the union which air forms with the inflammable principle, when it is disengaged from bodies by combustion, fermentation, putrefaction, or any other mode of decomposition; and from the mutual attraction of water and air, which is manifested by evaporation, and by the constant presence of aqueous particles in the atmosphere.

The laws of chymical analysis will hardly permit us to doubt, that the air, which is obtained from mild alcalies, calcareous earth, and various other substances, receives from them, when they are decomposed, the same contents which were united in them as constituent parts, while they were in their intire state. And their analysis invariably shews that air, water, and phlogiston, enter their composition.

From hence it seems to follow, as an immediate and obvious inference, that fixed air consists of these three ingredients, either united in bodies,
and

and discharged from them, already combined, or that it is formed in the atmosphere, by the concurrence and union of these principles. And all the phænomena, not only of fixed air, but also of phlogisticated air, may be solved by the action, and properties, of these ingredients.

The weight of fixed air, indicates that it contains a considerable portion of aqueous matter; and it is by means of this constituent principle, that it is miscible with water, in like manner as ardent spirits are, notwithstanding their inflammable nature. The phlogistic part of fixed air has been already considered.

Phlogistic matters are miscible with water, only in proportion as they contain a quantity of the aqueous principle in their composition. When the relative proportion of this constituent part, is less than that of the phlogiston combined in such matters, they are either immiscible with water, or only miscible in part.

Thus, spirit of wine, which is oil combined with water, unites with water, in all proportions.

Æther, which consists of spirit of wine, from which a considerable portion of its water has been separated by the vitriolic acid, is not miscible with water in all proportions: but, ten parts of water are requisite to the absorption of one part of æther.

Oil, which contains still less water in its composition,

position, does not, in any degree, mix with water.

Resinous substances do not combine with water, because their aqueous part is not in sufficient quantity to serve, as a medium, for the union of their phlogiston.

In gums, the relative proportion of phlogiston is much less than in resins, and that of the water is much greater: and by the intervention of their aqueous part, gums are readily miscible with water.

Resins, when united with a due proportion of gum, are by its mediation, also rendered soluble in water. But, if a less proportion of the gum be joined with the resin, only a part of the compound, resulting from this union, is disposed to mix with water, and a residuum is left, which is incapable of being dissolved in any aqueous liquor.

Fixed air seems to resemble these matters, which do not possess a sufficient quantity of the aqueous medium, to render them totally soluble in water. For, after a given portion of fixed air has been imbibed by water, a residuum remains, which is incapable of being absorbed by it, and is called phlogisticated air.

This air may be formed from fixed air, not only by the subtraction of water, but by the addition of the inflammable principle: as when phlogiston is communicated to fixed air by electric sparks, or
the

the vapours disengaged from a mixture of sulphur and iron filings.

The origin of phlogisticated air shews, that its difference, from fixed air, consists chiefly in its deficiency of water.

As metals contain no water, so the phlogiston, which arises from them during their calcination, does not produce fixed air, but phlogisticated air.

But vitriols, and all other saline matters, contain water as a constituent part, and therefore yield fixed air. Calces of metals also, which have received aqueous matter, in the process of their calcination, as white lead, and other calces which have absorbed water, together with air, from the atmosphere, also yield fixed air.

The fermentation, and putrefaction, of vegetable and animal substances, is effected by means of their moisture, and therefore, by these modes of decomposition, fixed air is produced.

Fixed air is more effectually formed by respiration, than by many other phlogistic processes, in consequence of the copious supply of the aqueous, as well as the phlogistic, principle, which the air receives from the lungs.

Fixed air may be formed from vegetable acids, but when it is thus constituted, it does not differ from that which is produced from alcalies, magnesia, calcareous spar, and various other substances, which yield no acid. It is therefore evident, that in each of these instances, it is formed by the combination

combination of some principles, which are common to all those substances.

These principles are water, and phlogiston. In vegetable acids, the phlogiston combined with the water, is equal, in quantity, to that which constitutes the inflammable part of spirit of wine: for radical, or concentrated, vinegar, is totally inflammable.

The acid state of vegetable matters is not essential to them, nor is it requisite to their production of fixed air. For, fixed air is producible from plants, when they are recent; when they are in a vinous state, and afford ardent spirits; and also when they are in a state of putrefactive fermentation. From whence it appears that in their acid, as well as in their recent, vinous, or putrefactive state, they yield fixed air, by means of their aqueous, and phlogistic, principles.

All fixed air, from whatever subject it is procured, or to whatever bodies it is transferred, consists, constantly and invariably, of the same materials, combined in the same proportions: otherwise it could not restore lime, caustic alcalies, or other matters, to their original mild state: because, these substances cannot be recomposed, but by the same proportion of their constituent principles, which they contained, before their decomposition.

Thus, lime cannot be restored to the state of mild calcareous earth, by water, or by pure dephlogisticated

phlogisticated air, because each of these principles consists of only one of the three ingredients, which are requisite for that purpose.

Nor can the recomposition of calcareous earth be effected by phlogisticated air, because it contains an excess of phlogiston, and a defect of water.

Compounds, formed of such relative quantities of any of these principles, as do not constitute fixed air, may acquire a due proportion of them, by an addition of the ingredients in which they are deficient.

Pure dephlogisticated air is reduced to fixed air, by the communication of aqueous, and phlogistic vapours, disengaged from bodies, by various modes of decomposition : these principles readily combine with air, on account of their great affinity to it.

Phlogisticated air, when agitated with water, receives into its composition a quantity of aqueous particles, sufficient to constitute it fixed air : and by that means, it becomes capable of precipitating lime, from lime water.

If the analysis, and recomposition, of calcareous earth be ever so often repeated, its analysis will always yield, and its recomposition will always require, the same relative quantities of air, water, and phlogiston.

Fixed air therefore, seems to consist of these three principles invariably, and constantly, combined in the same proportions.

I shall

I shall not here enter upon the consideration of any other æriform fluids, because they are foreign to my present inquiry.

I was led to an examination of the inflammable principle, by the changes, which it operates in coloured substances, both when it is in a detached and separate state, and when it forms a constituent part of fixed air, and is diffused throughout the atmosphere.

Fixed air has been frequently considered as a mere compound of air, and phlogiston. But, such a compound seems to approach nearer, in its nature, to phlogisticated air; as it is deficient in one of the principles, which is essential to fixed air.

I have endeavoured to point out some qualities of the inflammable principle, which have not hitherto been observed, or which have not been applied to the solution of the phænomena of elastic fluids. Such are, its solvent power; its power of effecting the mildness, and crystallization of alcalies; its strong affinity to calcareous earth, alcalies, and other substances which yield fixed air, whose similar, and correspondent, properties result from the phlogiston, which it contains as a constituent part.

I willingly submit these observations, to the candid judgment of those excellent philosophers, who have extended the knowledge of elastic fluids, by their instructive labours: amongst which, the
numerous

numerous experiments and observations of Dr. Priestley are the most conspicuous.

From the preceding experiments and observations it appears, that the colouring particles of flowers and leaves, are soluble in acid, and phlogistic, menstrua.

The other parts of vegetables consist of materials, similar to those which are contained in their flowers, and leaves, and undergo the same changes, from the same causes. I extracted from logwood, its colouring particles, by repeatedly boiling it in water. The wood, thus deprived of its tinging matter, no longer retained its yellow colour, * but was of a brown hue, similar to oak wood.

I macerated some pieces of logwood thus deprived of its colour, in aqua fortis, and, after they had undergone the action of that acid, they were washed in a sufficient quantity of water. The wood by these means was reduced to *whiteness*.

* Most authors, who treat of colouring substances, describe logwood, as a *red* wood. I have never procured logwood which was of any other colour, than *yellow*. It imparts yellow and orange colours to distilled water. Other waters extract a red tinge from it, by means of the alkali which they contain. These observations are also applicable to the other dying woods, to kermes, and various other articles of the *materia tinctoria*. I shall only add that the tinctures, infusions, and solutions, which are enumerated in the preceding table of coloured liquors have been described from careful and repeated observations.

By

By a similar treatment, fustic, and other dying woods, were deprived of their Colouring Matter, and became *white*.

I have hitherto shewn, that the Colouring Matter of plants does not exhibit any colour by reflection, but by transmission only; that their solid earthy substance is a white matter; and that it is the only part of vegetables, which is endued with a reflective power; that the colours of vegetables are produced by the light reflected from this white matter, and transmitted from thence through the coloured coat, or covering, which is formed on its surface by the colouring particles; that, whenever the colouring matter is either discharged, or divided, by solution, into particles too minute to exhibit any colour, the solid earthy substance is exposed to view, and displays that *whiteness*, which is its distinguishing character.

Animal substances do not afford any great variety of coloured products. But, in all those animal matters, which do exhibit colours, the colouring particles are endued with the same properties, and are regulated by the same laws, which prevail in vegetable substances.

The tinctures and infusions of cochineal (No. 59, 60.) and of kermes (No. 61, 62.) yield their colours, when light is transmitted through them, but do not reflect any colour.

The principal animal coloured substances are the bile, and the blood. I diluted, with distilled water,

water, fresh ox gall and examined it, in the vial (No. 63.) that part of it which was in the neck of the vial, and which was viewed by transmitted light, was yellow, the anterior surface reflected no colour, but appeared *black*.

Flesh consists of fibrous vessels containing blood, and is perfectly *white*, when divested of the blood, by ablution. The membranes, sinews, bones, and other solids, are *white*, and when they are freed from their aqueous and volatile parts, they are a mere white earth, unalterable by fire, and capable of imparting to glass an opaque whiteness.

Blood, diluted with warm water, was examined, in one of the vials. It transmitted a red colour; its anterior surface was almost, but not entirely, black. For it received a slight mixture of a brown hue, from some particles which were coagulated, and were suspended in the red liquor.

That I might procure blood, sufficiently diluted, and at the same time, perfectly and equably dissolved, I mixed as much red cruor, with spirit of sal ammoniac, as imparted to it a vivid red colour. The liquor, thus composed, was viewed in the vial, (No. 64). That part of it, which was contained in the neck of the vial, transmitted a bright red; that which was viewed through the anterior side of the vial, reflected no colour but was intensely *black*.

From these observations, it appears that the florid red colour of the flesh arises from the light

which is *reflected* from the *white* fibrous substance, and transmitted back through the red transparent covering, which the blood forms on every part of it.

The blood, whilst recently drawn, does not assume the appearance which is common to transparent coloured liquors, for, such liquors, when too massy to transmit light from their farther surfaces, are black. But blood, recently drawn, yields a red colour, in whatsoever masses it is disposed.

The colour, thus exhibited, arises from a white matter diffused throughout the blood. The white matter is easily separable from the red part of the cruor. This may be performed, by dividing the cruor, after it is coagulated, into thin pieces, upon which a sufficient quantity of water must be poured. The cruor communicates a red tinge to the water, which should be changed every day. After a few days, the water no longer receives any tinge, and the remaining masses of the cruor are, by these means, rendered perfectly *white*.

Thus it appears that not only the flesh, but also the blood itself, are white substances, tinged with red particles.

The red colour, which the shells of lobsters assume, after they are boiled, is a mere superficial covering, spread over the white calcareous earth of which the shells are formed, and may be easily removed by scraping, or filing the surface.

Before

Before this superficial covering is attenuated, by the heat, it is much denser, so that, in some parts of the shells, it appears black: as it is too dense to admit the passage of the light to the white substance of the shell, and back again. But where this transparent blue colour is spread thinner, and rarer, the light, reflected from the white substance of the shell, is transmitted back through the blue film, and yields a light blue colour.

The colour, of the shells of several species of eggs, is also merely superficial, and may be scraped off, leaving the white earth of the shell exposed to view.

Feathers, in like manner, owe their colours to thin layers of Coloured Matter, covering the white substance, of which they are principally formed: I scraped off the superficial colour from such parts of vividly coloured feathers, as were solid enough to admit of that operation, and, by this means separated the coloured layers from the white ground, on which they had been naturally spread.

The surfaces of the lateral fibres of feathers cannot be thus separated on account of their minuteness. But, as they appear, when viewed in a microscope, nearly to resemble, in their form, the feathers themselves, it seems probable that their colours arise from a similar matter, and conformation, in the smaller fibres, as in the grosser parts of the feathers.

The colours of all the animal substances, which have fallen under my observation, are effected in

the same manner as those of the specimens which I have here described.

In all these instances, the colours of the bodies are produced by the light reflected from a white substance, and transmitted back from thence, through a transparent coloured covering. The colouring particles have been extracted from such of the bodies, as were capable of yielding them to any proper solvents: and in their state of solution, as well as when condensed into a solid consistence, they have been constantly found to possess a power of transmitting colour, but to be devoid of any reflective power.

In the examination of some animal subjects, when the colouring matter could not be separated from the white substance, by chemical means, I have had recourse to mechanical methods of effecting their division. But, such methods can only be employed, when the principal part of the white substance is unmixed with the coloured coat or covering, which is spread upon its surface.

The mineral kingdom affords a great variety of coloured substances. These consist principally of earthy, and metallic matters.

The earths have been usually arranged in three classes, the siliceous, the calcareous, and the argillaceous, which is obtained purest in the earth of alum. To these, mineralogists have lately added magnesia, and terra ponderosa, which is the basis of spar. All these earths are perfectly
white,

white, when pure, and free from heterogeneous matters.

The colours, which they assume, are adventitious, and arise from phlogistic, or metallic, mixtures. Such compounds form ochreous, cupreous, and other metallic earths, and coloured clays; and boles: which may be artificially obtained, by precipitating metals from their solutions, and uniting them with calcareous, or aluminous bases.

Calcareous earth indurated constitutes marble; which may be tinged, by means of metallic solutions, with dyes which, both in their colours, and materials, are similar to those produced by nature.

From siliceous earths, flints are formed, which owe their colour to phlogiston, and when sufficiently heated, are rendered white, by the loss of their inflammable contents.

Siliceous earths impregnated with metals, form agates, cornelians, jasper, and coloured crystals.

The emerald, sapphire, topaz, hyacinth, and ruby are composed of a mixture of siliceous, calcareous, and argillaceous earths, and receive their colours from iron.

All these coloured stones may be imitated by glasses tinged with such phlogistic, or metallic matters, as enter the composition of the original substances.

Liquors, impregnated with phlogiston (No. 65, &c.) transmit coloured light, but do not reflect any colours. Nor do the glasses which derive their colours from inflammable, or metallic matters, appear coloured by reflection, but by transmission only.

From hence it is evident, that phlogistic, or metallic matters, when united with earths, do not reflect the coloured light: but are transparent coloured media, which transmit the light reflected by the particles of the white earths.

Metals, when in their entire metallic state, are endued with a strong reflective power. All the metals, except gold and copper, act equally upon all the rays of light, from which their whiteness arises.

Gold exhibits a white light, which is *tinged with yellow*. I have used this expression, because it appears, from experiment, that gold reflects a white light, and that its yellow colour is a tinge, which is superadded to its whiteness. The experiment is thus set forth by Sir Isaac Newton.*

“ Gold in this light, (that is, a beam of white
 “ light) appears of the same yellow colour as in
 “ day light, but by intercepting at the lens a
 “ due quantity of the yellow making rays, it
 “ will appear white like silver, as I have tried,
 “ which shews that its yellowness arises from the

* Newton. Opt. L. I. Part II. Prop. XI. Prob. VI.

“ excess

“ excess of the intercepted rays tinging that
“ whiteness with their colour, when they are let
“ pass.”

I have already shewn, by numerous experiments, in what manner coloured tinges are produced; and it uniformly appears, from all those experiments, that colours do not arise from reflection, but from transmission only.

A solution of silver is pellucid and colourless. A solution of gold (No. 18.) transmits yellow, but reflects no colour. This metal also when united with glass, yields no colour by reflection, but by transmission only.

All these circumstances seem to indicate, that the yellow colour of gold arises from a yellow transparent matter, which is a constituent part of that metal, that it is equably mixed with the white particles of the gold, and transmits the light which is reflected by them. In like manner as when silver is gilt, or foils are made by covering white metals with Transparent Colours.

But, these factitious coverings are only superficial, whereas the yellow matter of gold is diffused throughout the whole substance of the metal, and appears to envelop and cover each of the white particles.

In whatsoever manner the yellow matter of gold is united to its white substance, it exists in a rare state. For it bears only the same

proportion to the white particles of the gold, as that part of the yellow-making rays, which were intercepted, bears to all the other rays comprized in the white light of the sun.

Calces are metals, divested of their phlogistic principle, by menstrua, or by fire. The calcined particles are suspended in their solvents, and, together with them, form transparent liquors. The metals, thus dissolved, reflect no colours, but either transmit coloured light, or are pellucid and colourless.

It is proper here to explain the cause, why the metallic particles, which yield no colour, by incident light, when suspended in their solvents, are disposed to exhibit colours, when separated from their menstrua, and reduced to a calciform state.

Sir Isaac Newton has shewn, that when spaces, or interstices, of bodies are replenished with media of a different density, the Bodies are Opake; that those superficies of transparent bodies reflect the greatest quantity of light, which intercede media that differ most in their refractive densities; that the reflections of very *thin Transparent Substances* are considerably stronger, than those made by the same substances of a greater thickness.

On these grounds, the minute portions of air, or of the rarer medium, which occupies spaces void of other matter, reflect a vivid *White Light*, whenever their surfaces are contiguous to media, whose densities differ considerably from their own. So that,

that, every small mass of air, or of the rarer medium, which fills the pores, or interstices, of dense bodies, is a minute white substance.

This is manifest, in the whiteness of froth, and of all pellucid Colourless Bodies, such as glass, crystal, or salts, reduced to powder, or otherwise flawed. For, in all these instances, a *White Light* is reflected from the air, or rarer medium, which intercede the particles of the denser substances, whose interstices they occupy.

All pellucid Colourless Substances become opake and white, by the admixture of pellucid colourless media of considerably different densities: as in the instances which have been here adduced. And all Opake White Substances are rendered pellucid and colourless, by reducing them to uniform masses, whose component parts are, every where, of nearly the same density. Because, all reflections are made at the surfaces of bodies differing, in density, from the ambient medium; and, in the confines of equally dense media, there is no reflection.

Thus, opake white earths are reducible to Pellucid Colourless Glasses, by proper fluxes, and a sufficient degree of heat. When the particles of air and water, united in the small bubbles of which white froth consists, are separated from one another, each of them constitutes an uniform, Pellucid, Colourless Substance.

When

When particles of air, or of the rarer matter, occupy the interstices of any dense *Transparent Coloured Body*, the *White Light* reflected from those rare substances shines through the *Transparent Coloured Medium* which the particles intercede, and is tinged by it, according to the colour which it transmits.

Thus, an infusion of cochineal transmits a red colour, and its surface is *black*, when viewed by incident light. But, if this liquor be agitated, its surface is thereby covered with a red froth, whose colour is occasioned by the light, reflected from the globules of air inclosed in each of the bubbles, and transmitted back through the transparent films of red liquor, which cover them.

I tinged several masses of glass with metals so intensely, that they appeared *black*, except in such parts as, from their thinness, transmitted the Coloured Light. Pieces of these glasses were pulverized separately, and each of the powders, thus prepared, exhibited the respective colours, with which the several masses of glass had been tinged.

The action of such powders, on the rays of light, arises from the discontinuity of their parts, whereby the air is admitted into their interstices, and, by its reflective power, produces those appearances, which result from rare media contained

tained in the pores of Transparent Coloured Substances.

It is evident that calces, separated from metallic solutions, derive their power of exhibiting Coloured Light from the same causes, which prevail in those instances which I have here adduced, and explained. For, in proportion as the interstices of the calces are evacuated, by the deprivation of their liquid solvents, the air pervades those vacuities.

Vitriols, and other metallic salts, are formed from metallic solutions, by the evaporation of their aqueous part, excepting only such a portion of it as is essential to their crystallization.

These metallic salts are either coloured, or colourless, according to the solutions from which they are formed. Whilst their constituent principles remain united in due proportion, and order, they are pellucid. But when their watery part is disengaged, they lose their transparency, and texture, and are reduced to an opaque friable mass, or to powder.

In this state, air pervades the interstices which the water had evacuated, and reflects a white light, in consequence of the difference of its density from that of the matter which is contiguous to it; and as even the coloured vitriols, and other coloured metallic salts, contain a large proportion of colourless saline matter; when the water of their crystallization is expelled, their
metallic

metallic coloured particles are so diluted, that the mass appears almost white.

These effects are also produced by pulverizing, or otherwise flaving, metallic salts, but not so compleatly as by the expulsion of their water.

By calcination, the saline matter is driven off: and, when this operation is effectually performed, the calces consist of metallic particles, which are free from all extraneous matter, excepting only the *moleculæ* of air which occupy their interstices.

The air, which intercedes the particles of metallic calces, reflects the light more strongly than that which intercedes vitriolic particles. Because the calces of metals differ more, in their density, from air, than metallic salts differ from that fluid. Therefore, each *molecula* of air, which intercedes the metallic particles, powerfully reflects a white light, and consequently is itself a minute white body, such as is seen in the globules of air enveloped in the small bubbles of water which constitute white froth.

But, as the specific density of metallic calces greatly exceeds the specific density of water, the *moleculæ* of air, which intercede the metallic particles, reflect the light stronger than those which intercede the aqueous particles, in proportion to their difference of density with respect to that of the ambient substances, whose vacuities they occupy.

No

No substances, whose interstices are occupied by air, differ more from air, in their specific density, than metallic calces do. For which reason, the reflections made at the surfaces, which intercede those media, are extremely strong.

The Light, reflected from the molecularæ of air contained in the interstices of metallic calces, is transmitted through the thin Transparent Matter of the calces which cover them, and is thereby tinged, according to their respective colours.

It is evident that calces, obtained from Transparent Metallic Solutions, by the evaporation and expulsion of their aqueous, and saline, parts, consist of Transparent Matter: for, the metallic particles in the solutions, and in the calces, are the same, and the opacity, or transparency, of the solutions, and calces, arise from the difference of the media, which intercede the metallic particles in the one, or the other, of those states.

Calces, united with pellucid colourless glass, are transparent; and metallic glasses, which are formed by fusion of the calces, are also transparent. For they constitute solid, smooth, masses, devoid of such pores as are capable of admitting the entrance of air.

The existence of air, in the calces of metals, is clearly established by numerous chymical experiments. From these it appears, that metals, during their calcination, copiously absorb the
ambient

ambient air, and thereby acquire a considerable increase of weight. When they are again reduced to their metallic form, a quantity of air, equal to that which was acquired during the calcination, is disengaged, and the mass loses the adventitious weight, which it possessed during its calciform state.

Metals, calcined by heat only, act upon light in the same manner as those which have been previously dissolved, and afterward calcined. They agree, in the discontinuity of their particles; in their absorption of air, and their consequent increase of weight; and in their transparency, which is manifested, when they are mixed with pellucid glass, or other pellucid media, and when transparent metallic glasses are produced by their fusion.

Metallic precipitates, which are combined with some of the matters, by which they were dissolved, or precipitated, transmit the light which is reflected by those matters. When precipitates are disengaged from such extraneous parts, by ablution, calcination, or any other means, they are mere calces, such as have been already considered.

When oil, instead of air, is interposed between the particles of paints which are formed of the denser metals, such as vermilion, and minium, their colours are not perceptibly altered: because, although oil considerably exceeds air, in
its

its specific density, yet as it differs greatly in that respect, from the denser metallic powders, the *moleculæ* of oil, which intercede their particles, act upon the incident light so strongly that the reflections, effected by them, cannot be distinguished from those which are caused by rarer media.

When ochres, and other paints, which owe their colours to the rarer metals, are combined with oil, they assume a darker hue. Because the excess of the density of oil, over that of air, forms a sensible difference, when comparatively considered, with respect to the specific gravity of the rarer metals. From this cause, perceptibly less light is reflected from the *moleculæ* of oil, than from those of air, and consequently the mass appears darker.

When air is expelled from, and oil is united with, coloured powders, whose specific density is much less than that of metallic calces, the brightness of their colours is diminished in proportion as the powders approximate, in specific density, to the media which occupy their interstices. And when the specific density of these is nearly equal, there is no sensible reflection in the confines of their respective surfaces, and therefore the mass appears black.

Thus, when indigo, and other transparent vegetable paints, are united with oil, the air is thereby expelled from their interstices; and the
oil,

oil, which is admitted in its stead, from the nearness of its density, to that of the ambient powders, reflects no sensible light, so that the mass, which consists of such uniformly dense media, is black.

When smooth surfaces of dark-coloured marble, or slate, or of any other polished coloured substances, are scratched, the air enters into the interstices which are opened by this operation, and according to the excess of its rarity, over that of the masses whose particles it intercedes, it strongly reflects a whiter, or lighter-coloured, hue. But, when by polishing the surface, or filling the pores with a denser medium, the air is removed from them, the darker hue is restored.

From all the preceding experiments and observations, it appears that vegetable, animal, and mineral Coloured Matter is transparent; that it does not reflect colours, But exhibits them by transmission only, that Opaque Coloured Bodies consist of transparent matter, which covers opaque white particles, and transmits the light, which is reflected from them.

I shall, in the next place, examine the nature of Semipellucid Coloured Substances, which appear of one colour, when viewed by incident light, and of another, when viewed by transmitted light: and I shall endeavour to shew, from several experiments and observations, that, in these, as well as in Opaque Coloured Bodies,

no reflection is made by Coloured Matter, but by White, or Colourless, Particles only.

Semipellucid Substances, which appear of one colour when viewed by incident light, and of another colour when viewed by transmitted light, consist of pellucid media, throughout which White, or Colourless, Opaque Particles are diffused.

The opaque particles are disposed at such distances from each other, that some of the incident rays of light are capable of passing through the intervals which intercede them, and thus are transmitted through the semipellucid mass.

Some sorts of rays penetrate through such masses, whilst other sorts, which differ from them in their refrangibility, are reflected, by the White, or Colourless, Particles, and from thence are transmitted back through the pellucid part of the medium, which intervenes between the reflecting particles and the anterior surface of the mass.

When pellucid colourless glass is melted with arsenic, the arsenic is thereby divided into minute opaque white particles, which are equally diffused throughout the glass. If only a small quantity of arsenic is used in this compound, the white particles are rarely disseminated in it.

When glass, thus combined with a small proportion of arsenic, is held between the window and the eye, it appears Yellow or Orange

Coloured. When it is viewed by incident light, it exhibits a Blue Tinge. The yellow, or orange colour arises from the transmission of the less refrangible rays, from whose mixture that colour results. The more refrangible rays are not transmitted through the glass, but are reflected by the white particles, and pass back through the Transparent Medium, which is between those particles and the anterior surface of the glass.

I shall here cite from Sir Isaac Newton, a passage, * from which it appears, that from the mixture of those rays, which are transmitted, a yellow, or orange colour must be produced; and that those rays which were intercepted, and reflected, must compose a blue colour.

As the arsenical particles are equably diffused throughout the glass, with which they are combined,

* The letters R, and ϵ , refer to a figure in Sir Isaac Newton's Optics (L. I. Part. II. Prop. VIII. Probl. III.) which represents the rays of light, cast on a white paper after they have been refracted through a prism, and expresses the compound colours which result from the several mixtures of the differently refrangible rays. The following extracts relate to such mixtures of the rays, as produce blue, and orange colours.

“ At R, where the violet-making, indigo-making, blue-making, and one half of the green-making rays are mixed, their colours must compound a middle colour between indigo and blue.

“ At ϵ , the mixture of red, orange, yellow, and one half of the green, must compound a middle colour between orange and yellow.”

bined, consequently the spaces, which intervene between those particles, are equal to each other: and the space also which intervenes between the surface of the glass, and the arsenical particles which are nearest to the surface, is equal to the intervals which intercede the particles. And this may be farther shewn, by breaking such masses of glass; for, the fresh surfaces of every fragment will appear similar to the original surface of the whole mass.

From hence it is evident that, when a smaller portion of arsenic is mixed with glass, the intervals between the White Opaque Particles will be larger, and therefore, the less refrangible rays will be more copiously transmitted through them: and, in consequence of their loss, the more refrangible rays which are intercepted, and reflected, by the particles of arsenic, will exhibit a bluer colour, and recede farther from whiteness.

This observation is confirmed by experiment: for, although glass, which contains a small proportion of arsenic, appears blue by incident, and orange coloured, by transmitted light; if a large proportion of arsenic be combined with the glass, the compound, viewed by incident light, appears white, and no colour is transmitted through it, except it be made extremely thin. For, as the intervals between the particles, which are thus densely disposed throughout the glass, do

not admit the passage of the less refrangible rays, they are not separated from the more refrangible rays, but are conjointly intercepted and reflected, by the white particles, which are contiguous to the anterior surface, and therefore the mass appears white.

When a bright light, such as the sun, or the flame of a candle, is viewed through a thick mass of such glass, so many of the more refrangible rays are intercepted, that the transmitted rays compound a Red Colour.

The glass, of which bottles are usually made, affords another instance of a semipellucid substance, which exhibits a blue colour by incident, and a yellow or orange colour, by transmitted light.

This sort of glass, when in its perfect state, transmits a green colour, which it owes to the iron contained both in the vegetable ashes, and in the sea sand, which enter into its composition.

The flux, by which the materials of this glass are fused, is so loosely connected with them, that it is disengaged by exposure to a red heat. In proportion as the glass is decomposed, by the loss of its flux, the earthy particles, which are no longer dissolved, become Opaque. If the glass be withdrawn from the fire, whilst only a small part of the flux is disengaged, the mass consists of Transparent Glass, throughout which the opaque earthy particles are disseminated.

If

If the glass be surrounded with white sand, or other earthy substances, and exposed to a greater heat, it entirely loses its transparency, and texture, and assumes the appearance of porcelain or earthen ware, as M. Reaumur first observed. I have continued this process so far, that the whole of the flux was disengaged from the other materials of the glass.

After having exposed, in a strong, continued heat, the neck of a bottle, filled, and surrounded, with white sand, I observed that all the flux had quitted the glass, and united with the sand, which had been in contact with its external, and internal, surfaces. For the space, which had contained the glass, was occupied by a loose sandy powder, and on each side of that space, the white sand was united into a firm, consistent, mass, which represented a mould, whose cavity was of the exact form, and size, of the neck of the bottle, from whose flux it received its shape, and consistence.

When the glass, from the degree of heat, to which it has been exposed, is reduced to such a state, that it consists of a Transparent Medium, mixed with Opaque White Particles, it exhibits a blue colour by incident light, and a yellow, or orange colour, by transmitted light. For, the more refrangible rays being intercepted and reflected by the white earthy particles, pass back through the space, which intervenes between

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those

those particles and the anterior surface of the glass; by which a blue colour is compounded. And the less refrangible rays, pervading the semipellucid medium, compound a yellow, or orange colour, as has been already explained, with respect to the glass combined with arsenic.

When a greater degree of heat is applied to the glass, by which the opaque earthy particles become more copious, the mass appears almost white. Because, as in this dense state of the opaque particles, almost all the differently refrangible rays are intercepted, and reflected, by them, a hue nearly approaching to whiteness arises from their mixture.

The quantity of ferruginous particles, in this mass, is so inconsiderable, and the colour produced by them is so diluted by the numerous reflections from the white opaque particles, that it becomes almost imperceptible.

The atmosphere acts upon the rays of light, in the same manner as the semipellucid media which have here been described.

The blue colour of the sky is not produced by reflection from the atmosphere, considered as an uniform extended mass. For such a mass would reflect the colour, from its surface. As reflections are made only at the surfaces of bodies, which differ, in density, from the media, which are contiguous to them; but the atmosphere does not reflect any coloured light from its surface.

Thus,

Thus, when the air contained in a chamber, or in a court or area, is viewed through a glass window, the surface of the atmosphere, which is contiguous to the glass, reflects no colour, but is pellucid and colourless. Nor is any colour reflected by the surfaces of air, which are adjacent to water, crystal, or any other media, placed in contact with it.

The air contains a great variety of extraneous particles, which although they are almost, or entirely, imperceptible when separate, yet, when viewed collectively, are capable of producing visible reflections, by their united powers.

When a beam of light is admitted through a small hole, into a dark chamber, innumerable motes are seen floating in the air, which is thus illuminated. These minute bodies vividly reflect a white light around them, in every direction, so that they are distinctly seen from every part of the dark chamber. Such particles occupy all parts of the air which have been hitherto observed.

The atmosphere abounds in volatile, and evaporable matters, which are disengaged from natural bodies, by several operations, as fermentation, effervescence, putrefaction, the action of fire in volcanos, and various other means of decomposition.

Many of the particles, which are separated by such processes, differ considerably, in density,

from the air. And, as they are, for the most part, colourless, they reflect a white light, and therefore may be considered as white particles, diffused throughout the pellucid colourless air.

In this respect, the atmosphere is similar to the semipellucid medium, which is formed by diffusing the white particles of arsenic, throughout pellucid colourless glass. In both these substances, whilst the white, or colourless, particles are rarely disseminated through the transparent medium, the less refrangible rays are transmitted through the intervals which intercede the particles, and compose an orange, or red, colour: but, the more refrangible rays are intercepted, and reflected, by the particles, and the mixture of those rays produces a blue colour.

In the air, as well as in the solid semipellucid media, when the white particles are more densely arranged in the pellucid medium, the intervals which intercede them are diminished, and the distance, between the surface of the pellucid medium, and the white particles, is also reduced.

In this state of the atmosphere, as the greatest part of the yellow, orange, and red rays, are intercepted, and reflected, together with the more refrangible rays, they, by their union, exhibit a hue nearly approaching towards whiteness.

When the part of the atmosphere, which is near the surface of the earth, is occupied by
gross

gross vapours, this mixture of air with aqueous, or other particles, is white: and, the anterior surface, as well as the interior parts, of the compounded medium, appears to be densely stored with white particles. Fogs, which consist of gross vapours, seem chiefly to differ from clouds, in their depression, and contiguity to the surface of the earth.

When such vapours are elevated higher in the air, and form clouds, they reflect the white light of the sun, and thereby appear white, whenever its incident rays fall upon them intire and undivided.

As the reflective particles are not equally diffused through every part of the pellucid air, of which the atmosphere principally consists, it frequently happens, that large tracts of air are furnished with only such a portion of subtile contents, as qualify them to reflect a blue colour; whilst others are so densely stored with reflective particles, that they constitute clouds.

The inferior parts of the atmosphere which are adjacent to the surface of the earth, constantly abound in dense exhalations, more than the higher regions.

Naturalists have not hitherto obtained any considerable insight into the nature, and origin, of the particles by which the transparency of the air is impaired, except as far as relates to
aqueous

aqueous meteors. It is certain that some of the most extensive, and permanent vapours, which have been observed in the atmosphere, were not formed of aqueous or humid matter.

The mist, which obscured the air, during the summer of the year 1783, was remarkable for its extent. For, it involved almost all Europe, a part of Asia, and of Africa, and perhaps reached much further: its altitude was so great, that the Alps were immersed in it.

In most parts of Europe, the air, during the prevalence of this vapour, was unusually dry. For, the hydrometer did not rise to the point which denotes moisture: salt crystallized in brine pits, before the ordinary period; and other processes, which depend upon evaporation, were accelerated.

Several other curious observations, relative to this subject, are contained in an account written by M. Senebier of Geneva.*

When the air is replenished with very dense vapours, it transmits only the less refrangible rays, from whose mixture an orange, or red, colour is produced. Distant mountains covered with snow, clouds, or other white substances,

* The paper of this excellent philosopher is inserted in the Journal of the Abbé Rozier (Anno. 1784. May.) The same collection contains also instructive accounts of that subject by M. Toaldo, Professor at Padua, M. Lamanon, and M. Marcorelle, Baron d'Escalle. (Jan. 1784.)

which

which are opposed to the rays transmitted through the atmosphere, reflect their light, and thence assume their colours.

Sir Isaac Newton attributed the various colours of the clouds, to the different magnitudes of the particles, whereby he conceived that they were qualified to reflect the differently refrangible rays. M. Melvill has more accurately remarked, that the colours of the clouds, at sun-rising and setting, do not depend on the sizes of their component particles, but arise merely from the colours of the rays transmitted through the tract of air which is contiguous to the horizon, and that they indiscriminately reflect the rays which are incident upon them.

This observation perfectly agrees with the phænomena. But the author of this remark does not seem to have formed any clear or precise conception of the constitution of the atmosphere, and its action on the rays of light. He supposed, that the atmosphere is similar to Transparent Coloured Liquors.* But, it

* *Physical Essays*: Edinburgh. 1756. vol. II. p. 79.
“ To understand why the sun’s rays, by passing through a
“ greater and greater quantity of air, change by degrees
“ from white to yellow, thence to orange, and lastly to
“ red, we have only to apply to the atmosphere, what Sir
“ Isaac Newton says (Book I. of his Optics, Part. II. Prop.
“ X.) concerning the colour of transparent liquors in
“ general.”

appears

appears from several parts of this inquiry, that Transparent Coloured Liquors do not reflect any colour, but appear black when viewed by incident light: therefore, the atmosphere, which exhibits colours by reflecting the incident light, does not, in its optical properties, resemble such liquors.

Mr. Melvill not only acquiesces in the general opinion, that colours are produced by the reflection of the several rays, from the Colouring Particles: but he extends his doctrine of the reflective power of those particles, so far as to attribute to them the action on light, whereby opaque bodies are sooner heated by the sun-beams, than transparent ones. “As (according to him) each *colorific particle* of an opaque body, by the reaction of the particles of light, must be somewhat moved, when the light is *reflected* backward and forward between the same particles, it is manifest, that they likewise must be driven backward and forward with a vibratory motion.” *

With respect to this hypothesis, I shall only observe, that, as the Colouring Particles of bodies do not reflect the rays, but appear black by incident light, even when contiguous to air: they cannot, according to any optical law, exercise a reflective power, when they are in contact with the internal parts of media, whose density

* Ib. p. 20.

greatly exceeds the density of air, and thereby approaches much nearer to that of the colouring matter itself.

When distant objects are seen, through a considerable tract of such rare air as constitutes a blue sky, those objects assume the blue colour of the air. For they must be considered as reflective bodies, acting on the incident light, in the same manner as the reflective particles, which are diffused through the air. So that the reflected light passes back, from them, mixed with the blue rays, which are reflected by the minute extraneous particles of the atmosphere.

If a denser atmosphere, or a longer tract of it, intervene between the objects and the eye, they become fainter and less distinct, and appear whiter; as the rays reflected from them are mixed with the whiter hue, which numerous particles communicate to the air.

By the interposition of a still greater quantity of the reflective particles of the air, the objects disappear. For the weak reflected light of distant objects, cannot, like the strong light of luminous bodies, penetrate semipellucid substances, so as to transmit through them even the less refrangible rays.

These, and all the phænomena of the atmosphere, may be imitated, and explained, by artificial semipellucid substances, such as have been here described.

Sir

Sir Isaac Newton, and others, have supposed that the green colour of the sea is produced by the reflective power of the water. But, actual observations do not confirm, or agree with this opinion.

When sea water is admitted into a reservoir, which does not exceed a few inches in depth, the water appears pellucid and colourless. It is therefore manifest, that no colour is reflected from its surface. Consequently, the water of the sea, considered as an uniform extended mass, does not reflect any colour.

Sea water abounds in heterogeneous particles. Magnesia is procurable from its analysis: calcareous earth may be obtained in the same manner, and manifests itself in the numerous shells, corals, and other calcareous concretions, which are formed in it. The strata, which compose the bottom, and shores, of the sea, also furnish various saline, metallic, bituminous, and other matters. The animals, and vegetables, which it nourishes, contribute to the production of extraneous particles. All these receive an addition from the rivers, which constantly discharge their contents into the sea.

Many of the earthy, and other, particles accede, in density, so near to water, that, when they intercede that medium, their reflective power must be very weak: but, as they do not entirely coincide with water, in density, they
must

must be endued with a small degree of reflective power. Therefore, although they may be invisible, when separately viewed, yet when the forces of a great number of such minute bodies are united, their action on the rays of light becomes perceptible; some sorts of rays being reflected by them, whilst others are transmitted through their intervals, according to the quantity of reflective matter, which the rays arrive at, in the internal parts of the water.

The opacity of the sea, caused by the numerous reflections from its internal parts is so considerable, that extensive masses of it cannot be seen through: even although the obstacle arising from the colourless light, reflected from its surface, be removed, by viewing the lower part of the water, through a dark tube immersed under the surface, at the bottom of which a polished glass plate is joined.

The nature and origin of the particles, which diminish the transparency of the water of the sea, have not hitherto been examined, except as far as relates to the more obvious saline, and earthy, substances which are commonly obtained from its analysis.

Yet, although the matter, of which these particles are formed, is not ascertained, it is certain that they are endued with a somewhat greater reflective power, than those which are suspended
in

in the atmosphere, when in its rarest state. For the reflective particles, of the rarest sky, exhibit a blue colour, when viewed by incident light; but the reflective particles of the sea act upon a greater portion of the more refrangible rays; whereby they exhibit a green colour; and, (as Dr. Halley found from actual observation) transmit a rose colour, which is red, inclining to violet, at such depths as only the less refrangible rays can penetrate.*

Sir Isaac Newton observes that those parts of thin plates of water, or air, which by transmitted light appear of a colour compounded of red and

* Newton. Opt. L. I. Part. II. Prop. X. Probl. V.
 “ Of this kind, is an experiment lately related to me by
 “ Mr. Halley, who in diving deep into the sea in a diving
 “ vessel, found in a clear sun shine day, that when he was
 “ sunk many fathoms deep into the water, the upper part
 “ of his hand, on which the sun shone directly through the
 “ water, and through a small glass window in the vessel,
 “ appeared of a red colour, like a damask rose, and the
 “ water below, and the under part of his hand, illuminated
 “ by light reflected (*) from the water below looked
 “ green.” (*) All the green light, by which the under
 part of the hand was illuminated, was not reflected from
 the medium, which was beneath the vessel: for, a part of
 it was reflected from the ground, over which the vessel was
 placed. The light, thus reflected from the ground, was
 tinged green, by passing through the small depth of water,
 which intervened between the ground, and the vacant space
 in the vessel, under the hand: whereby the rays, reflected,
 from the ground, were mixed with the green rays reflected
 from the internal parts of the sea water.

violet,

violet, exhibit a green colour by reflected light.* These he calls opposite colours, by which term he usually expresses those transmitted colours which are seen in the part of the medium, which is opposite to the reflected colours, and *vice versa*.†

All colours, transmitted by semipellucid substances, are opposite to those which the substances exhibit when viewed by incident light. And in proportion as Transparent Coloured Media grow opaque, by the formation, or reception, of white, or colourless particles, the colours which they transmit recede farther and farther from the original colour, which the medium transmitted whilst it was transparent, until at last the mass grows so opaque, that no rays are any longer transmitted.

I shall not enter upon any farther explanation of the manner in which the water of the sea acts upon the rays of light, as the observations which have been made respecting the air, and other semipellucid media, are likewise applicable to the optical appearances of the sea.

The semipellucid substances, which I have hitherto described, reflect the more refrangible, and

* Ib. Prop. V. Theor. IV. Exp. X. "If the red and violet be intercepted, the remaining yellow, green and blue, will compound a green."

† Ib. L. II. Part. I. Obs. IX. "By looking through the two contiguous object glasses, I found that the inter-
Vol. II. R jacent

and transmit the less refrangible rays. Such media, for the most part, act upon the rays in a similar manner.

The reflection, and transmission, of the more or less refrangible rays, depend upon the powers of the reflective particles. The reflective, as well as the refractive, power of bodies being in a great measure proportionable to their specific gravity.

Instances rarely occur either of natural, or factitious semipellucid substances, in which the reflective particles are of so great a specific gravity, as qualifies them to reflect the less refrangible rays, such as red, or orange; and, which at the same time are so minute, and so rarely diffused, that intervals are left between them, sufficient to admit the passage of the rays.

The specific gravity of gold is much greater than that of any other known substance, by which glass can be equably tinged. I therefore,

“ jacent air exhibited rings of colours, as well by transmitting light, as by reflecting it.

“ I found that white was opposite to black, red to blue, yellow to violet, and green to a compound of red and violet. That is, those parts of the glass were black when looked through, which when looked upon appeared white, and on the contrary. And so those which in one case exhibited blue, did in the other case exhibit red, and the like of the other colours.”

judged

judged it expedient to examine in what manner the particles of that metal, combined with glass, would, under various circumstances, act upon the differently refrangible rays.

For this purpose, I combined gold with pellucid colourless glass, after the manner of Kunckel, Cassius, and others, by which a Transparent Coloured Glass was composed, which transmitted a bright red colour, but appeared black by incident light.

I exposed several pieces of this red glass to the heat of burning coals; by which means, they lost their transparency, and underwent an alteration in their texture. For, when the red glass is thus reheated, the particles of gold, uniting with some of the other ingredients of the glass, form Opake Moleculæ, which reflect all the rays, excepting the violet, and thereby appear by incident light, of a light brown hue.

If all the rays were equally reflected, the mass would appear white, when viewed by incident light. But, the privation, of even a small portion of them, impairs the whiteness, and reduces it to a brown hue, which is lighter, or more intense, as a greater or less quantity of the different rays are wanting in its composition.

The brown hue, reflected from the glass, which is here instanced, arises from the white light reflected from the Opake Particles, to which a small proportion of all the rays, excepting the violet, is superadded.

The violet rays are transmitted through the glass, and, therefore, it appears vividly tinged with a violet colour, when looked through.

In proportion as the transparency of this red glass is impaired, the transmitted colour recedes from red, till it becomes violet: according to the law which all Transparent Bodies observe, when Opaque Particles are introduced into, or formed in them, so as to render them semipellucid.

This experiment manifests the strong reflective power, with which the particles of gold are endued, according to their specific gravity.

In this kind of glass, and in all other Semipellucid, as well as Opaque, Coloured Substances, colours are reflected from White, or Colourless Particles only, and are transmitted through the Transparent Parts of the Media.

It is not necessary to extend this subject, by a description of Semipellucid Liquors, as they act according to the same laws, and afford the same appearances, as the solid media, which have been already instanced.

In the preceding experiments, I have preferred the use of semipellucid glasses, because they are not apt to be decomposed, or suffer any variation in their texture; and therefore are disposed, constantly, and equably, to exhibit the same colours.

The coloured light, which is transmitted through Semipellucid Substances, passes through the intervals

tervals which intercede the Opaque Particles diffused through them. For, when the Opaque Particles are so densely arranged, that they intersect, and cover, the interstices which lie between them, the passage of the rays is obstructed, and none of them are transmitted: but, the mass ceases to be semipellucid, and becomes opaque.

The same cause of obstruction to the passage of the rays takes place in Transparent Coloured Bodies, when the Colouring Particles are densely arranged: so that the light is intercepted and absorbed, by the colouring matter, and the mass, consequently, appears black, in whatsoever direction it is viewed.

From several experiments, and observations, which I have made, in the course of this inquiry, it appears, that the rays of light are transmitted through Transparent Coloured Substances by means of a power, with which they are endued; and, that those Media transmit Coloured Light with the greatest strength, which have the greatest refractive power.

The strong refractive, and reflective, power of inflammable bodies has been observed by Sir Isaac Newton. But, the power, of such bodies, to transmit the rays otherwise than by refracting them, has not, I believe, hitherto been noticed.

The following experiments prove, that the Transmissive Power, of Inflammable Coloured Media is much stronger, than the Transmissive

Power of Coloured Media, which do not abound in phlogistic matter.

To a dilute solution of green vitriol in distilled water, I added a small quantity of an aqueous infusion of galls. The liquor, composed of these ingredients, transmitted a blue colour, which, although perfectly distinct, and unmixed with any other hue, was not vivid, but appeared as a coloured substance not acting upon a sufficient quantity of the rays of its own colour.

I made a tincture, by digesting green vitriol in spirit of wine, and, to a portion of this tincture, diluted with a farther addition of spirit of wine, I applied a small quantity of a strong spirituous tincture of galls. This liquor, thus prepared, transmitted a blue colour, greatly excelling in beauty and brightness.

The strength, of the transmissive power of inflammable media, is manifest from a comparative view of these processes, and others which have been already instanced.

Sir Isaac Newton attributed the colours of natural bodies, to the several sizes and densities of their particles, by which, according to him, they *reflect* several sorts of rays, and thereby appear of several colours.

It has been shewn, throughout this inquiry, that the Colouring Particles are not endued with a reflective power, but produce their several colours by transmitting the several sorts of rays.

The

The experiments, made with thin plates of glass, water, and air, from which Sir Isaac Newton inferred, that the several colours of natural bodies arise from the several sizes and densities of the particles, were executed with so much skill and precision, and have been so often successfully repeated, by later inquirers, that they are firmly established.

But, the doctrine of a reflective power existing in the Colouring Particles, does not appear to be deducible from those experiments, nor is it conformable to any subsequent observations.

Sir Isaac Newton observed, that thick plates of glass yield * rings of colours, in the same manner as the thin plates, from whose appearances he deduced this explanation of the colours of natural bodies.

The Duke de Chaulnes has proved, that none of the colours, exhibited by such thick plates, are reflected by the anterior surface of the glass; but that the rays, after having passed through the first surface, to the farther surface, are thence reflected back. †.

May it not from hence be inferred, that, since the action of thick plates, in exhibiting colours, is analogous to that of thin plates, the colours, even in these, are not produced by reflection from the anterior surface, but by a remoter reflection,

* Newton. Opt. L. II. Part. IV.

† Acad. Paris. Ann. 1755. p. 136.

and by a subsequent transmission through the pellucid glass.

From all the experiments which I have here adduced, it uniformly appears, that no Coloured Light is reflected from the anterior surfaces of Opaque, Semipellucid, or Transparent Coloured Bodies. For, in these, the light is reflected by the superficies which intercedes the transparent part of the medium, and the substance which is behind it: and the light, thus reflected, is transmitted back, through the transparent part of the medium, which intervenes between the reflective surface, and the anterior surface.

In these respects, the Coloured Media, which have been examined throughout the course of this inquiry, agree with the plates of glass observed by the Duke de Chaulnes.

If the experiments, which have been made with thin Transparent Colourless Substances, and those which have been performed with Coloured Media, be jointly considered, it will appear that the effects, which Sir Isaac Newton has attributed to Reflected Light, should have been applied to Transmitted Light. And the observation of this great philosopher, relative to the connection between the colours of natural bodies, and the size and density of their particles, if thus modified, will coincide with his own experiments, and all the others which have been made subsequent to them.

In a former work, I have shewn by a series of experiments, that the changes of colour, which Permanently Coloured Substances undergo, are made in a regular order, accordingly as the sizes of their colouring particles are diminished, or augmented.

I have here adduced some examples of the influence of density and of phlogiston, on the colours of the bodies.

Besides these means, by which the colours of some substances are affected, I have frequently observed that there is another cause, by which changes are produced in Transparent Coloured Media, not only in the degree, but also in the species of the colour.

These changes arise from the greater, or less obstruction which the rays meet with, in their passage through the interstices which intercede the Colouring Particles; according to the thicknesses of the media, and the quantity of colouring matter diffused through them.

Transparent Coloured Media act upon the rays of light, more simply and uniformly, than Semipellucid Substances: because, in these a greater variety of phænomena result from the different forces of the Opake Particles: by which some of the rays are reflected, whilst others are transmitted.

Although all Transparent Coloured Media transmit a less quantity of the incident rays,
in

in proportion as the passage through their interstices is obstructed; some of those media, during the decrease of their transmitted light, do not vary the species of their colour: but, in other Transparent Coloured Media, the transmitted colours are changed, by the resistance to which the rays are opposed, during their passage through the interstices.

The changes, which are thus effected in Transparent Coloured Media, generally proceed in one and the same order. So that, in proportion as the passage of the more refrangible rays, through such substances, is obstructed, the less refrangible rays, by their greater momentum, penetrate the medium and are transmitted through it.

From the mixture of the less refrangible rays, which are thus transmitted, the mass exhibits either a red, or some colour inclining to red, in proportion as a greater or less quantity of the more refrangible rays are intercepted.

It is probable, however, that some instances may be found, of media whose changes of colour do not coincide with this general rule. Especially, if such media owe their colours to phlogistic matter, or to particles which differ greatly in density, from the pellucid part of the substances through which they are diffused.

I have not met with any observations, relative to the changes of colour, arising from the
cause

cause which is here considered, excepting such as relate to yellow liquors, which are apt to transmit orange, and red colours, in proportion as the rays are transmitted through greater thickneses of such media.

Sir Isaac Newton, in the following passage, has attributed, to red liquors, the property of transmitting these colours, according to the different thickneses of the liquors. “ A red liquor
“ in a conical glass held between the light and
“ the eye, looks of a pale and dilute yellow at
“ the bottom where it is thin, and a little higher
“ where it is thicker grows orange, and where
“ it is still thicker becomes red, and where it is
“ the thickest the red is deepest and darkest.” *

The liquor, which was the subject of this observation, was, probably, an aqueous or spirituous infusion of some of the woods which are used in dying red. For, these transmit a yellow, orange, or red colour, according to their thickneses, or tenuity.

But, red liquors do not transmit orange, or yellow, colours, even when spread thin. Several red liquors are enumerated in the table p. 166, such as the nitrous solution of cobalt, the red infusions of flowers, the red juices of fruits, and berries; and several others. When these liquors are disposed in thicker, or thinner, masses, they

* Newton. Opt. L. I. Part. II. Prop. X. Probl. V.

do not vary the species of their colour, but only transmit a diluter, or more intense red.

Nor do red glasses appear yellow, or orange, when divided into the thinnest plates.

These Transparent Red Media, from the interception of the transmitted rays, suffer no other change, except the diminution, or loss, of their colour, whereby they assume a darker hue, or become black.

As the changes of colour, thus effected in yellow liquors, have been already observed, I shall not mention any experiments relative to them, but shall advert to other media, whose phenomena have not, I believe, been hitherto noticed.

I digested, in spirit of wine, a sufficient quantity of sap green, which is an expressed vegetable juice, inspissated, and dried. When the spirit of wine was saturated with this colouring substance, it was filtered through paper, and afterwards poured into a small flint-glass bottle which was of the form of a wedge, or triangular prism.

That portion of the coloured liquor, which was contained in the angular part of the bottle, and which, consequently was the thinnest, transmitted a vivid green colour; that portion, which was in the widest part of the bottle, transmitted a bright red colour; the intermediate portion, which was between the green and the red, transmitted a yellow colour; but the yellow
was

was much inferior to the two other colours, both in quantity and brightness. The liquor, when viewed by incident light, appeared black.

Sap green infused in distilled water, and viewed in a similar bottle, transmitted the same colours. But, the green was not so copious, or so vivid, as in the spirituous tincture; and the proportion of the yellow was likewise diminished.

These experiments afford a farther instance of the superior transmissive power of inflammable media; since the more refrangible rays are more copiously, and more vividly, transmitted by the spirituous tincture, than by the aqueous infusion.

By infusing grass, and other green leaves, in spirit of wine, I obtained a tincture, consisting of the spirit of wine saturated with the colouring matter of the leaves. This was examined in the same manner as the preceding liquors: it transmitted a bright green, where it was thinnest; and a vivid red, where it was thickest: but, the intermediate yellow was scarcely perceptible. This, as well as the two former liquors, appeared black, when viewed by incident light.

I infused litmus in distilled water, and having thus procured a coloured infusion, I filtered it, and examined it, in the same manner as the liquors, which have been already described. This infusion transmitted an azure blue colour, where it was thinnest; and a bright red, where it was thickest. The intermediate colour was purple. This liquor

quor also appeared black, when viewed by incident light.

When these liquors are sufficiently diluted, each of them transmit the more refrangible rays, even when they are contained in the widest part of the prismatic bottles. For, the greater thickneses of diluter coloured liquors, contain no more coloured particles, than thinner masses, which are more intensely coloured.

These phaenomena seem to indicate, that the power, by which the several rays of light are transmitted through Coloured Media, is inherent in the Colouring Particles themselves, and therefore, is not confined to the surfaces of such media. For, if the transmissive force was exerted at the surfaces only, thinner plates of Coloured Substances would act upon the rays, as powerfully as thicker masses. But, it appears, from experiment, that, in proportion as the rays pass through different thickneses of coloured media, they exhibit colours, differing, not only in degree, but, frequently, in species also.

The sun's light, by which bodies are illuminated, consists of all the rays, by which a white light is compounded. These rays, in their entire and undivided state, are incident upon the Opake Particles of Semipellucid Substances; and, upon the Colouring Particles of Transparent Coloured Substances, whenever those media are exposed to the light.

When

When the rays accede to the opaque particles of semipellucid substances, some sorts of them are reflected back, from the anterior surface of those particles: the other sorts of rays, which are not reflected back, are diverted from the direction which is opposite to the anterior surface of the opaque particles, and, passing through the intervals, between the particles, are transmitted through the mass.

When the rays are incident upon the particles of Transparent Coloured Bodies, none of them are reflected back, because the colouring particles are not endued with any reflective power. But, some of the rays are either stopt at the anterior surfaces of the particles, or are diverted into such directions, as render them incapable of passing towards the farther side of the mass, and, consequently such rays cannot be transmitted. The rays, which are not thus intercepted, or dispersed, are transmitted, in the same manner as those which pass through semipellucid media.

Thus it is evident, that the coloured rays, which are transmitted through semipellucid substances, are *inflected* by the Opaque Particles: and those which are Transmitted through Transparent Coloured Substances, are *inflected* by the colouring particles.

I have already shewn, that those media transmit coloured light with the greatest strength, which have the greatest refractive power. From the preceding

preceding observations, it appears, that the particles of coloured media inflect the several sorts of rays, according to the several sizes, and densities, of the particles ; and also, in proportion to the inflammability, of the media which owe their colour to them : and it is manifest, that the transmission of coloured rays depends upon their inflection.

All these observations are conformable to Sir Isaac Newton's doctrine, that the rays of light are reflected, refracted, and inflected, by one and the same principle, acting variously in various circumstances.

I have hitherto investigated, and explained, the powers and operations, by which the rays of light are transmitted through coloured media ; and, have shewn that, in Opake coloured Bodies, they are reflected by the Opake particles, which are constituent parts of such bodies, and, that the light, thus reflected, passes back through the Transparent Colouring Matter, with which the opake particles are covered.

It appears, both from the analysis of Opake Coloured Bodies, and from several other experiments and observations, that the matter, by which they reflect the light, consists of white particles.

The solid parts of animals, and vegetables, are principally composed of calcareous earth, which is a perfectly white substance. This earth also abounds in the mineral kingdom, as well as the siliceous, and argillaceous, earths, and magnesia, which

which also are perfectly white, when pure, and divested of adventitious matters.

All these earths constitute Transparent Colourless Media, when they are vitrified, together with proper fluxes; or when they are dissolved in colourless menstrua. And the saline masses, which are obtainable from their solutions, are transparent and colourless, while they retain the water which is essential to their crystallization, and are not flawed, or reduced to powder.

But when, by such means, the interstices of those masses are evacuated, or opened, they are rendered white and opaque, by the admission of air, or of a rarer medium.

The earthy particles, which form the solid parts of bodies, generally exceed, in density, the other constituent particles, which they intercede. For, in the composition of bodies, earths are, for the most part, combined with aqueous, ærial, saline, or inflammable matters; all of which are greatly inferior to earths, in their specific density. And, therefore, the surfaces of the earthy particles, which are contiguous to such media, must reflect the rays of light, with a force which is proportionate to their excess of density.

The reflective power of bodies does not depend merely upon their excess of density, but upon their difference of density, with respect to the ambient media. Therefore, Transparent Colourless Particles, whose density is greatly inferior to that of the media which they intercede, also powerfully

reflect all the sorts of rays, and thereby become white.

Of this kind are the air, or other rare fluids, which occupy the interstices of liquors; of transparent solid bodies, flawed, or reduced to powder, or otherwise minutely divided; of porous solid substances; of calces of metals; and in general of all denser media, into whose interstices such rarer particles are admitted.

These observations are grounded upon Sir Isaac Newton's doctrine, relative to the transparency, and opacity of Colourless Substances. And from thence it may be deduced, that white opaque bodies are constituted by the union or contiguity of two, or more, Transparent Colourless Media, differing considerably from each other, in their reflective powers.

Such white substances are instanced in froth, emulsions, or other imperfect combinations of pellucid liquors, milk, snow, salts calcined or pulverized, glass, or crystal, reduced to powder, white earths, paper, linen, and even those metals, which are called white by the mineralogists and chymists. For those metals do not appear white, unless their surfaces be rough. Because, the surfaces of polished metals do not afford interstices, into which air, or other rare fluids capable of reflecting light, can be admitted.

But, when interstices are opened on the surfaces of metals, by roughening them, the air occupies those interstices, and its molecu^{læ}, according to
the

the great difference of their density, with respect to that of the metal, vividly reflect a white light.

The rough surfaces of metals consist of minute irregular prominences, and cavities, from which the rays are reflected, in different directions, whereby they are blended and intermixed, and, by their mixture, constitute whiteness.

But, the polished surfaces of metallic mirrors equably, and regularly, reflect the several incident rays, according to their several angles of incidence: so that the reflected rays do not interfere with each other, but remain separate and unmixed, and therefore distinctly exhibit their several colours.

From hence it is evident, that white surfaces cannot act upon the light, as mirrors: because all the rays, which are reflected from them, are promiscuously, and disorderly blended.

Nor can the surfaces of mirrors appear white, except when white objects are casually opposed to them: because the rays which fall upon them from coloured objects, are reflected separately, and distinctly, whereby colours are exhibited.

In forming ornamental works of silver, artists sometimes avail themselves of the contrast, between the resplendent whiteness of the unpolished parts of the metal, and the regular reflections which are displayed by its polished parts.

White metals are peculiarly adapted to the formation of mirrors, as their surfaces are capable of being polished, by which they are qualified

equably, and regularly, to reflect the incident rays; as their reflective power is proportionate to their specific density, which is very great; and as they are disposed indiscriminately to reflect all the differently refrangible rays.

Mercury, silver, lead, and tin, are pellucid and colourless, when dissolved in their proper menstrua. In the solutions of other metals, some colouring particles are mixed with the colourless particles. The opacity, and the vivid lustre of the entire metals, which consist of those pellucid particles, united with phlogiston, arise from the powerful reflection of the surfaces, which intercede the metals and the air.

Metals do not owe their shining appearance to their metallic particles, but to their phlogiston. For, calcination, which disengages the inflammable principle from metals, deprives them also of their lustre.

The reflective power, of the inflammable principle, is so great, that it imparts, to various pellucid colourless substances, a shining appearance, perfectly resembling the lustre, and hue, of metals.

Plumbago, which has a metallic appearance, and lustre, consists of two substances, which, when separate, are not only pellucid, and colourless, but absolutely invisible. For its sole constituent parts are phlogiston, and fixed air. *

* D. Scheele, in Act Stockh. 1778.

Many marcasites, which scarcely yield to any of the metals, in lustre, do not contain any metallic particles, but consist principally of sulphur, which itself is composed of phlogiston, and vitriolic acid.

Nor is the lustre, and metallic appearance, confined to substances which abound in phlogiston: for, it is exhibited by the surfaces of several Pellucid Colourless Media, which vividly reflect the light; from the difference between their density, and that of the ambient media; from their glossy smoothness or polish; or from various other causes.

Mr. Melvill has clearly explained the silver-like appearance, which drops of water exhibit, when they lie on the leaves of colewort, and some other vegetables. He observed, that the lustre of those drops, is produced by a copious reflection of light, from the flattened part of their surfaces, contiguous to the plant; that the drops, when they have that appearance, do not touch the plant, but are kept at some distance from it, by the force of a repulsive power, or medium, which occupies the intervals between the drops and the leaves: that, as the surfaces of the leaves are considerably rough and unequal, the under surfaces of the drops become rough likewise, and so by reflecting the light copiously, in different directions, assume the resplendent whiteness of unpolished silver.*

* *Physical Essays*: Edinburgh. 1756. vol. II. p. 25.

When Pellucid Colourless Glass is broken, it sometimes happens that, the fresh surface of the fragment is very smooth and glossy. If such a fragment of glass be so placed, that the fresh broken part may be seen at the farther surface, that part cannot be distinguished by the sight, from a similar portion of glass covered with quicksilver.

This effect is produced, by the copious reflection of light from the broken part, which greatly exceeds in smoothness, the original surface of the glass. For, melted glass, from its tenacious consistence, assumes, whilst it cools, a surface less glossy than those which are exposed, by breaking it. Many other like instances may be adduced.

These phænomena afford much insight into the nature, and cause, of opacity. As they clearly shew, that even the rarest Transparent Colourless Substances, when their surfaces are adjacent to media greatly differing from them in refractive power, may thereby acquire a perfect opacity, and may assume a resplendency, and hue, so similar to that of white metals, that the rarer pellucid substances cannot, by the sight, be distinguished from the dense opaque metals. And, this similarity to the surfaces of metals occurs, in the rare pellucid substances, not only when, from the roughness of their surfaces, they resemble unpolished metals in their vivid whiteness; but also when, from their
smoothness,

smoothness, they resemble the polished surfaces of metals.

Metals seem to consist entirely of Transparent Matter, and to owe their apparent opacity, and lustre, solely to the copious reflection of light from their surfaces. The analogy between the metals and Transparent Media, as far as respects their optical properties, will appear from the following considerations.

(1) All metals, dissolved in their proper menstrua, are transparent. (2) By the union of two or more transparent media, substances are constituted, which are similar to metals, in their opacity and lustre, as has been instanced in plumbago, and marcasites. (3) The Transparent Substances of metals, as well as of those minerals, by their union with Phlogiston, acquire their strong reflective powers, from which their lustre and opacity arise. (4) The surfaces of pellucid media, such as glass, or water, assume a metallic appearance, when by their smoothness, their difference of density with respect to the contiguous media, or any other cause, they are disposed copiously to reflect the light.

From all these considerations, it is evident, that opake substances are constituted by the union, or contiguity, of Transparent Colourless Media, differing from each other in their reflective powers; and, that, when the common surface, which intercedes such media, is plane, equal, and smooth, it

reflects the incident rays equally, and regularly, as a mirror: but, when the surface is rough, and unequal, or divided into minute particles, it reflects the incident rays irregularly, and promiscuously, in different directions, and consequently appears white.

As the surfaces of pellucid colourless media are disposed indiscriminately to reflect all the rays of light; so white opaque substances, which are compounded of pellucid colourless media, retain the same disposition, which is indifferent to all the sorts of rays.

It has been already shewn, throughout the course of this inquiry, that coloured matter does not reflect any light; but, that reflective media act indiscriminately on all the different rays. It does not appear from the optical phænomena, which have hitherto been observed, that nature affords any kind of matter endued with a power of reflecting one sort of rays, more copiously than the other sorts. Consequently, no reflective substances are capable of separating the differently refrangible rays, and thereby producing colours.

There are several experiments, and observations, in Sir Isaac Newton's Optics, from which it might have been inferred, that coloured light is not reflected from coloured matter, but from white or colourless matter only.

Although that great philosopher supposes, that all coloured bodies reflect the rays of their own colours,

colours, more copiously than the rest, yet he observes, that “ they do not reflect the light of their
“ own colours so copiously as white bodies do.
“ If red lead, for instance, and a white paper, be
“ placed in the red light of the coloured spectrum
“ made in a dark chamber by the refraction of a
“ prism, the paper will appear more lucid than
“ the red lead, and therefore reflects the red-
“ making rays more copiously than red lead
“ doth.” *

If it be supposed, that the red particles of the minium reflect the red rays, more strongly than the rest, what reason can be assigned, why minium should not exhibit the red rays as vividly as white paper, which acts indifferently on all the rays.

But, if it be considered that, in opake coloured bodies, the rays, which are reflected from white reflective matter, pass back through the Transparent Coloured Media, with which the reflective matter is covered, it will evidently appear, why the coloured light reflected from white paper, is more copious and bright, than that which is exhibited by red lead.

A considerable part of the incident light is lost, in passing through Transparent Coloured Media. Therefore, the light reflected immediately from the white paper, must be more copious and lucid, than that which has undergone a diminution, in its passage to, and from, the reflective particles

* Newton. Opt. L. I. Part. II. Prop. V. Exp. 15.

of the Opaque Coloured Body, through the Transparent Coloured Medium.

When a small portion of colouring matter is mixed with a colourless medium, the mass appears tinged with colour; but, when a great quantity of colouring matter is added, the mass exhibits no colour, but appears black. Therefore, to attribute to colouring matter a reflective power, is to advance an inexplicable and contradictory proposition: for, it is asserting, that, in proportion as more reflective colouring matter is opposed to the incident light, less colour is reflected; and that, when the quantity of colouring matter is very great, no colour at all is reflected, but blackness is thereby produced.

From these arguments, it might have been shewn, that the reflective power does not exist in colouring matter, but in Opaque White Substances only. Nevertheless, in this disquisition, I have not entirely relied on arguments drawn from a few, known and obvious, appearances, but have endeavoured, by numerous experiments, to ascertain the cause of the colours of natural, as well as artificial bodies, and the manner in which they are produced.

M. Euler observed, * that the colours of bodies are not produced by reflection. He supposes that the coloured rays are emitted by the colorific particles. This hypothesis, however, is not agreeable to experiment. For, as the colouring matter

* Acad. Berlin, Ann. 1752. p. 262.

acts upon light, by transmission only, it is evident that bodies do not appear coloured either by reflecting, or emitting the rays.

I have not attended to any other hypothesis, which are unsupported by experiments.

Sir Isaac Newton, and, I believe, all later philosophers, except M. Euler, have attributed to colouring matter a reflective power. And the artists, whose works depend upon the preparation, and use of colouring materials, seem, in general, to have adopted the same theory.

As an instance of this agreement, I have cited, from M. Hellot, one of the most skilful and intelligent authors, who have treated of the Art of Dying, a passage which comprizes his opinion respecting the action of the tinging particles on the rays of light.*

All the other writers, on the same subject, appear to agree in that established opinion: but,

* “ Hellot. *Art de la Teinture des Laines.* 1772, p. 117. Nous ne connoissons, jusqu’ a présent, que deux plantes, qui donnent le bleu, après leur préparation; l’une est l’Isatis ou Glastrum, qu’on nomme Pastel en Languedoc, et Vouede en Normandie; leur préparation consiste dans la fermentation continuée presque jusqu’ à la putréfaction de toutes les parties de la plante, la racine exceptée; par conséquent, dans un développement de tous leurs principes, dans une nouvelle combinaison et arrangement de ces mêmes principes, d’où il résulte un assemblage de particules infiniment déliées, qui, appliquées sur un sujet quelconque, y *réflechissent* la lumière bien différemment de ce qu’ elles feroient, si ces mêmes particules étoient encore jointes à celles que la fermentation en a séparées.”

they

they seem rather to have yielded to the authority of Sir Isaac Newton, and other theorists, than to have appealed to the operations of their own art, from which the real cause and origin of colours is obviously deducible.

The Art of Dying consists, principally, in covering white substances, from which light is strongly reflected, with Transparent Coloured Media, which, accordingly to their several colours, transmit, more or less copiously, the several rays reflected from the white substances.

The Transparent Coloured Media themselves reflect no light: and it is evident that, if they yielded their colours by reflecting, instead of transmitting, the rays, the whiteness, or colour of the ground on which they are applied, would not anywise alter, or affect, the colours which they exhibit.

Such an erroneous conception of the principles of the art, cannot fail greatly to obstruct its progress, and improvement. All colouring matter is black, when viewed by incident light, and all substances incline to blackness, in proportion as they are copiously stored with tinging particles.

The Artist therefore, who confines his inquiries to substances which reflect the light, cannot be successful in his endeavours to discover new dying materials: and, if he is led, by experience, to extend his researches to other substances, his practice contradicts his principles; by which his views
are

are obscured, and bounded within the narrow limits of accidental observation.

The knowledge of the optical properties of colouring matters, is also essentially requisite to their due preparation and use. As the practice of dying, in its present state, is not regulated by any scientific rules, it is seldom improved by the introduction of new processes: and the methods of varying the uses of the materials, which are already known, are rarely ascertained without repeated trials.

All the operations of the art, excepting only a few which have arisen from accidental discoveries, owe their origin to remote ages.

We learn from the testimony of the sacred writers, as well as of the later historians, that the Indians, Egyptians, Phœnicians, and other ancient nations, excelled in the art of dying. From the accounts, which are delivered down to us, of the colouring materials which they used, and of the clothes which were dyed with them, we find evident proofs, that they were acquainted with the principles, as well as the practice, of the art.

The ancients did not attribute a reflective power to the colouring matter; but held, that the dyed clothes reflected less light, in proportion as they were more copiously stored with tinging particles. They estimated the richness and intenseness of the dye, by its approach to blackness.

Pliny, who has recorded many curious circumstances relative to the arts, describes indigo, when undiluted,

undiluted, as a *black* substance. * The same author informs us, that the species of Tyrian dye, which was most esteemed, was of a rose colour *inclining to black*; † and that the red was inferior to that which was blacker. ‡ He accurately distinguishes the bright red colour, which is transmitted through the dyed clothes, from the dark hue, which they exhibit when viewed by incident light. ||

The inattention of later philosophers, and artists, to the reflective, and transmissive, qualities of the constituent parts of Coloured Substances, has, doubtless, impeded the progress and improvement

* Plinii, L. XXXV. C. 6. Ab hoc maxima autoritas Indico. Ex India venit harundinum spumæ adhærescente limo. Cum teritur *nigrum*. At in diluendo mixturam purpuræ cæruleique mirabilem reddit.

† Ib. L. IX. C. 36. Purpuræ florem illum tingendis vestibus expetitur, in mediis habent faucibus. Liquoris hic est minimi in candida vena, unde pretiosus ille bibitur *nigrantis* rosæ colore subluens.

‡ Ib. L. IX. C. 38. Rubens color *nigrante* deterior.

|| Ib. L. IX. C. 38. Laus ei summa, color sanguinis concreti, *nigricans aspectu*, idemque *suspectu resurgens*.

It appears from the following passage, cited from Macrobius, that the dealers in dyed clothes were accustomed to consider the colours, which they yielded by transmission, as well as those which they afforded, when viewed by incident light. “Cum de Tyriæ purpuræ, quam emi jusserat, obscuritate quereretur (Augustus) dicente venditore, erige altius et suspice, his salibus usus est: Quid? ergo ut me populus Romanus dicat bene cultum, in solario ambulaturus sum?” Macrob. Lib. II. Saturn.

of the science of optics, and of the arts which are dependent upon it. This experimental research was undertaken, for the purpose of examining the optical qualities of such substances.

During the course of my inquiry, I have observed, that the transition from physical experiments, to practical operations of dying, is easy and obvious. For, the experiments, which I have made, with a view of investigating the origin and cause of colours, have guided me to the discovery of several bright and permanent dyes, in the execution of which I have, principally, used cheap and common ingredients, that have not before been applied to such purposes.

I do not doubt, that a clear, and comprehensive, view of the principles of the art will open, to the artists who practise it, a fertile source, from which, with certainty and facility, they may derive the discovery of new materials, and of the most advantageous means of employing them.

The art of painting, also, will receive great advantage, from an accurate and precise conception of the principles, by means of which the colouring matters, endued with a reflective power, may be distinguished from others which transmit the rays, but do not reflect them.

The works of many painters greatly excel in the clearness and brightness of their colouring.*

but

* Several of the greatest masters practised a method of colouring, which was, in some respects, conformable to the

but, it is unquestionable that a scientific knowledge of the nature of the colours, which they used, would have enabled even the greatest masters to have communicated, to those works, a still higher degree of excellence.

I shall not regret the labours which I have bestowed on the subject of these pages, if they contribute to the advancement of those useful and elegant arts, which are of much importance to a commercial nation; or if, by the disclosure of physical truths, they extend the bounds of science, or open new paths to its improvement.

the true principles of optics, and of their art. One of our most eminent painters has observed, from a minute and accurate examination of some of the most capital pictures of Titian, Tintoret, Paul Veronese, and other Italian, Flemish, and Dutch masters, that they painted with transparent colours, upon a white ground. This practice was carried to the highest degree of perfection by Correggio. That great colourist grounded his pictures with black and white only: and by the delicacy, clearness, and brilliancy of the transparent colours, which he laid on the grounds thus prepared, he gave to his compositions a peculiar force and relief, and a near resemblance of nature. Few modern artists have been able to comprehend the means, by which those effects were produced. Leonardo Da Vinci, in his instructive Treatise of Painting, recommends the use of white grounds, and transparent colours, as the true method of procuring the most brilliant colouring. Cap. 100. “*Sempre à quelli colori, che vuoi che habbino bellezza, prepararai prima il campo candidissimo, e questo dico de’ colori che sono trasparenti, perche a quelli che non sono trasparenti, non giova campo chiaro.*”

EXPERI-

EXPERIMENTS and OBSERVATIONS on FERMENTS and FERMENTATION; by which a MODE of exciting Fermentation in MALT LIQUORS, without the Aid of YEAST, is pointed out; with an ATTEMPT to form a new Theory of that Process. By THOMAS HENRY, F. R. S. Read April 20, 1785.

Nec manet ulla sui similis res; omnia migrant;
Omnia commutat Natura et vertere cogit.

LUCRETIVS.

OF all the processes of chemistry, there is, perhaps, none, the phænomena of which have been less satisfactorily explained, than those of Fermentation. The writers on Chemistry have been content to describe the several appearances, the progress and result of fermentation, and have declined any inquiry into its primary causes, or into the mode by which the changes, induced by it, are effected in bodies, which are the objects of its action.

Within these few years, great changes have taken place in the theory of Chemistry. The
Vol. II. T important

important discoveries of Black and Priestley, and of several other philosophical chemists, who have endeavoured to emulate their examples, have happily explained many of the operations of chemistry, which were, before, wholly unintelligible: and the present time forms one of the most distinguished æras in the history of that science. We now understand the nature of lime and of alkalis; the difference between a metal and its calx; the cause of the increase of weight in the latter, and of its decrease when returned to a metallic form. The constitution of atmospheric air has been demonstrated—Various gases resembling air, in many points, but differing from it in others, have been discovered; and, among these, an ætherial fluid, superior in its properties to common air, and capable of supporting life and combustion more vigorously and durably. Our acquaintance with this pure fluid, which forms the vital part of common air, seems to promise much enlargement to our chemical knowledge, in the investigation of its various combinations; and we have already derived much information, relative to the constitution of the acids, and of water, from the researches of philosophers into the nature of pure air.

Of the gases which have so much engaged the attention of the pneumatic chemists, fixed air, or, as it has more properly been denominated by

Sir

Sir Torbern Bergman, aërial acid, was that which first attracted their notice. This gas which had been remarked, even by Van Helmont, to be discharged, in great quantities, from liquors, in the vinous fermentation, was found by Dr. Priestley, to be again miscible, with them; and he proved that, on the presence of this gas, the briskness and pleasantness of these liquors depended, and that, when deprived of it, they became vapid and flat.

But though the Hon. Mr. Cavendish had proved the separation, and ascertained the quantity of this gas, discharged in fermentation, and though Dr. Priestley had early made the above-mentioned observations, it does not appear to have occurred to these philosophers, that this gas was the exciting cause, as well as the product, of fermentation.

It is a fact well known to brewers of malt liquors, that wort, contrary to what takes place in liquors more purely saccharine, as the juice of the grape, cannot be brought into the vinous fermentation, without the addition of a *ferment*; for which purpose yeast or barm, which is a viscid frothy substance, taken from the surface of other masses of fermenting liquor, has been, commonly, used.

But the nature of this substance, much less its mode of action, has not been considered, with

that degree of attention, which one would have expected should have been excited by so extraordinary an agent. We are told indeed that, a vinous ferment induces the vinous, that, a ferment of an acetous kind brings on the acetous fermentation, and a putrid one, that fermentation which ends in putrefaction. But we receive no more information, relative to the manner in which they produce these effects, than we do with regard to fermentation itself.

Before I endeavour to deliver any theory of ferments or of fermentation, I shall relate a number of facts which, have led to a few thoughts on the subject; and having mentioned the phenomena attendant on the process, as described by other chemists, shall then proceed to offer an hypothesis, with the greatest diffidence—a diffidence which nothing could enable me to surmount, but the kind indulgence I have so often experienced in this Society. And on no occasion have I stood more in need of their candour than on the present one; as the obscurity and intricacy of the path, on which I am entering, the almost total want of guides, and my inadequate abilities to clear away the obstacles, throw light on the dark parts, and point out those that may be traversed with ease and certainty, place me in a situation truly difficult. Indeed I was in hopes to have rendered what I have to offer, less imperfect, but my son's unfortunate accident,

has

has so engaged my thoughts, and added so much to my necessary avocations, that I have been able to devote but a small portion of my time to scientific pursuits.

Soon after Dr. Priestley had published his method of impregnating water, with fixed air, I began to prepare artificial Pyrmont water, by that means; and early observed that water, so impregnated, though it at first shewed no sparkling when poured into a glass; yet after it had been kept in a bottle, closely corked, for some days, exhibited, when opened, the sparkling appearance of the true Pyrmont water.* This I attributed, and perhaps not unjustly, to the gas, which had been more intimately combined with the water, and reduced to a kind of latent state, recovering its elasticity and endeavouring to escape.

Having, one day, made some punch with this water, and, having about a pint of it remaining, after my friends had retired, I put it into a bottle, capable of containing a quart, and corked the bottle. On opening it, at the distance of three or four days, the liquor, when poured out, creamed and mantled, like the briskest bottled

* Various methods have since been devised of forcing such a quantity of gas to combine, or, at least, to mix, with water, as immediately to communicate to it this appearance.

cyder. An old gentleman, to whom I gave a half pint glass full of it, called out in raptures to know what delicious liquor he had been drinking, and earnestly desired that, if I had any more of the same, I would give him another glass.

Dr. Priestley, as has been already mentioned, had informed us that fixed air, thrown into wine or malt liquor, grown vapid, restored to them their briskness and pleasant taste. On impregnating some vapid ale with fixed air, I was disappointed in not finding the effect, immediately produced. But after bottling the ale and keeping it closely stopped for four or five days, it was become as brisk as ale, which, in the common way, has been bottled several months.

In the year 1778 I impregnated, with fixed air, a quantity of milk whey, which I had clarified for the purpose of preparing some sugar of milk, and bottled it. In about a week, the whey in one of the bottles, which had been so loosely corked, that the liquor had partly oozed out, was remarkably brisk and sparkling. Another bottle, which was not opened till the summer of 1782, contained the liquor, not in so brisk a state, but become evidently vinous, and without the least acidity, perceptible to the taste.

I now began to suspect that fixed air is the efficient cause of fermentation; or, in other words, that the properties of yeast, as a ferment, depend on the fixed air it contains; and that yeast is little else than fixed air, enveloped in the

the mucilaginous parts of the fermenting liquor. I therefore determined to attempt the making of artificial yeast.

For this purpose, I boiled wheat flour and water to the consistence of a thin jelly, and, putting the mixture into the middle part of Nooth's machine, impregnated it with fixed air, of which it imbibed a considerable quantity. The mixture was then put into a bottle, loosely stop-ped, and placed in a moderate heat.

The next day the mixture was in a state of fermentation, and, by the third day, had acquired so much of the appearance of yeast, that I added to it a proper quantity of flour, kneaded the paste, and after suffering it to stand, during five or six hours, baked it, and the product was bread, tolerably well fermented.

I now determined to make a more satisfactory experiment. The wort, obtained from malt, it is known cannot be brought into a state of fermentation, without the aid of a ferment; for which purpose yeast is always used. If, therefore, by impregnating wort with fixed air, I could bring on the vinous fermentation; if I could carry on this fermentation so as to produce ale, and, from the ale, procure ardent spirit, I imagined that I should be able to announce to the world, a mode of procuring newly fermented liquors, in most climates, and in most situations.

I, accordingly, procured, from a public house,

two gallons of strong wort. It had a disagreeable bitter taste, owing either to bad hops, or to some substitute for hops. A large part of the liquor was impregnated, in Nooth's machine, with fixed air, which it seemed to absorb very rapidly and in large quantity. When it was thus impregnated, it was mixed with the other part, and poured into a large earthen jug, the mouth of which was stopped with a cloth; and placed in a degree of heat, varying from 70°. to 80°. In twenty-four hours the liquor was in brisk fermentation, a strong head of yeast began to collect on its surface; and, on the third day, it appeared to be in a state fit for tunning. It was therefore put into an earthen vessel, such as is used in this country, by the common people, as a substitute for a barrel, for containing their small brewings of fermented liquors. During the space of near a week, previous to the stopping up of this vessel, much yeast was collected on its surface, and occasionally taken off; and by means of this yeast, I fermented wheat flour, and procured as good bread, as I could have obtained, by using an equal quantity of any other yeast.

The vessel was now stopped up; and, in about a month, tapped. The liquor was well fermented, had a head or cream on its surface, and though, as might be expected from the description of the wort, not very pleasant, yet as
much

much so, as the generality of the ale brewed at public houses.

A part of the ale was submitted to distillation; and, from it, a quantity of vinous spirit was produced, which is submitted to the examination of the Society. But, the vessel being broken, before the distillation was finished, the quantity it would have yielded was not ascertained. However, that which was obtained, appeared not to differ much in quantity, from what an equal portion of common ale would have afforded.

As I had lost my notes, and was obliged to make out the preceding account, from memory, I designed to repeat the experiments again; but various engagements prevented me, till the latter end of August 1784. Of these experiments the following notes are taken from my journal.

August 30, I procured two gallons of common ale wort, two quarts of which were, in the evening, impregnated, but not saturated, with fixed air. The impregnated liquor was, then, added to the other part, and, about midnight, placed, in a large jug, within the air of the kitchen fire, where it remained during the night. In the morning no signs of fermentation. At five o'clock P. M. only a slight mantling on the surface. Apprehending the quantity of gas to have been too small, a bottle, with a perforated stopper and valve, containing an effervescing mixture of chalk and vitriolic acid, was let down
into

into the wort. At nine o'clock, the discharge of air, from the bottle, was going on briskly, and the wort seemed to be fermenting. At eleven o'clock the bottle was withdrawn, the fermentation being commenced, beyond a doubt; the surface of the liquor having a pretty strong head—Temperature of the wort 80° —at the outside of the vessel 78° .

September 1st, seven o'clock, A. M. the fire having been low during the night, the fermentation was less brisk—temperature of the wort reduced to 72 , and probably had been lower during the night, as the fire was now increased. The liquor was stirred up, placed in a situation where the thermometer pointed to 82° . and the effervescing mixture was again immersed. It was withdrawn at noon, and the thermometer standing at 92° , the wort was removed farther from the fire—At four o'clock, P. M. the head of yeast was strong, and at eleven o'clock was increased.

September 2d, nine o'clock, A. M. the liquor was judged to be in a proper state for tuning. It was accordingly removed into the vessel, before described, and carried into the cellar at eleven—at noon, a high head of yeast was running over the top of the vessel—some of it was taken off, and in two hours the head was equally strong.

September

September 3d, the fermentation proceeded regularly this day; and on the 4th I had collected so much yeast as to make a loaf with it, which, when baked, weighed about two pounds. The loaf was well fermented, good bread, having no peculiar taste, except a slight bitterness, proceeding from the wort having had too large a proportion of hops. Though, from the time in which the yeast had been collecting from so small a quantity of liquor, its fermenting power might have been expected to have been impaired.

September 5th the liquor was again covered with a plentiful head of yeast; and the fermentation was suffered to proceed to the 12th, when the vessel was closed, in the usual manner.

I intended, in a few weeks, to have committed the liquor to distillation; but my thoughts were unfortunately directed, to an object which engaged my most anxious attention; and my wort was neglected till the latter end of February; when, on tapping the vessel, the liquor, from having been kept so long, under such disadvantageous circumstances, and, perhaps, from too great heat in the fermentation, and the too long continuance of it, had passed from the vinous to the acetous state, and was become excellent allegar.

As I had obtained a vinous spirit from the former parcel of wort, I was not sorry for this event, as it was going a step farther than I expected,

pected. For I had now obtained yeast, bread, ale, ardent spirit, and acetous acid. A specimen of the last is now produced to the Society.

I flatter myself that these experiments may be of extensive utility, and contribute to the accommodation, the pleasure, and the health, of men, in various situations, who have hitherto, in a great degree, been precluded from the use of fermented liquors; and be the means of furnishing important articles of diet and of medicine. Not only at sea, but in many situations in the country, and at particular seasons, yeast is not to be procured. By the means I have suggested, in these experiments, fresh bread and newly fermented malt or saccharine liquors may, at any time be procured; and of how much importance, this may be, and how great the improvement to the malt decoctions recommended by the late Dr. Macbride, I shall not at present stay to expatiate on; as the subject may be too much connected, with the practical part of physic, to come within the limitations drawn by the Society. But, in domestic œconomy, its uses are very obvious; and perhaps in none more so, than the ready mode, which the preceding experiments teach, of reviving fermentation when too languid—the sinking of a bottle, such as I have described, in my *Essay on the Preservation of Water, at Sea, &c.* * with an effervescing mixture of chalk and vitri-

* London, 1781. See also, Plate 1, Fig. 1. Vol. II.

olic acid, appearing to be fully adequate to the purpose, and being, I believe, sufficient for impregnating the wort, without any other contrivance. This discovery therefore may, perhaps, be of no small utility in public breweries, and I would recommend it to the attention of persons concerned in the brewing trade.

Let us now proceed to describe the circumstances necessary to, and the phænomena attending fermentation, as described by chemical writers; and then endeavour to form some theory which may account for them.

Sugar, the juices of ripe fruit, and malt are all more or less disposed to run into fermentation. But before this can take place, it is necessary they should be diluted with water, so as to bring them to a liquid state. A due degree of heat is also requisite, as the fermentation succeeds best when the temperature varies from 70 to 80 degrees.

When the fermentation takes place, a brisk intestine motion is observable in the liquor; it becomes turbid, some fæculæ subside, while a frothy scum arises to the surface. A hissing noise is observed, and a quantity of gas is discharged, which has been proved to be fixed air. The liquor acquires a vinous smell and taste; and, from being heavier, becomes specifically lighter, than water. During the progress of the process, the temperature of the liquor

is

is higher than that of the surrounding atmosphere, with which it is necessary that a communication be preserved. After some days, these appearances begin to decline. If the process be rightly conducted, and stopped at a proper period, a liquor, capable of yielding vinous or ardent spirit, is the result. If the process has been too slow and the degree of heat insufficient, the liquor will be flat and spiritless; but, if these have been too rapid and excessive, it will pass into the acetous fermentation, to which indeed it is continually tending. But the more ardent spirit is generated, the less speedy will be the change to the acetous state.

During the progress of the acetous fermentation, which will even proceed in closely stopped vessels, no separation of air is observable, nor any striking phenomena. The liquor gradually loses its vinous taste, and becomes sour, and a gross sediment falls to the bottom; while a quantity of viscid matter still remains, enveloping the acid, which may be separated from much of the impurity by distillation.

The progress of these processes is accelerated by the addition of ferments, to the action of which it has been supposed necessary, that they should have passed through the state of fermentation into which they are intended to bring the liquor to which they are added; and that it was not possible to bring the farinaceous infusions
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into the vinous fermentation, without the aid of matter already in that state. This the preceding experiments have proved to be an ill founded notion, as it appears that fixed air, obtained from calcareous earth by means of acids, produces the effect, as perfectly as when the ferment has been taken from a fermenting liquor.

In fermentation, it is said, new arrangements take place in the particles of the liquor, and the properties of the substance become different from what it before possessed. But what these arrangements are, or how these properties are changed, we are not told. Dr. Black, I am informed, declares he is unacquainted with any satisfactory theory.

But perhaps facts, especially some *late* chemical discoveries, may throw light on the matter, and enable us to advance some conjectures, that may tend, at least, to lay the *foundation* of a theory.

1. Sugar is an essential salt, containing much oily, viscid matter. During its combustion it repeatedly explodes; a proof that it contains not only much inflammable matter, but also a quantity of air. Malt is saccharine, united to much viscid mucilaginous, matter.

2. If nitrous acid be added to sugar, the inflammable principle of the latter is seized by the acid; the whole, or at least one of the constituent parts of which is thereby converted into nitrous
gas,

gas, and flies off in that form. By repeated effusions of this acid, more gas is formed, and the remainder of the sugar is changed into crystals, having the properties of an acid, *sui generis*, and which has been denominated, by Bergman, *saccharine acid*. *

3. Saccharine acid is resolvable by heat, into some phlegm, a large quantity of inflammable and fixed air, both of which contain latent heat, and into a brownish residuum, amounting to $\frac{1}{10}$ of the weight of the acid. Fixed air is supposed to consist of pure air united to phlogiston; and inflammable air, to be almost pure phlogiston.

4. Water is found to be formed by the union of pure air, and inflammable gas, deprived of their latent heat; for, if these two elastic fluids be exploded together, in a close vessel, over mercury, the whole is converted into water of the same weight, as that of the air and gas, jointly. In the process much heat is evolved. Again, if water, in the form of steam, be forced to pass through a tube, containing iron shavings, strongly heated, the water, according to Messrs. Watt, and Lavoisier, is decomposed; the phlogiston passes off, united with heat, in the form of inflammable gas, while the *humor*, or dephlogisticated water, unites to the calx of the metal, from which it may be again obtained, in the

* Bergmanì *Opuscula Chemica*, vol. I. Art. de Acido Sacchari.

form of pure air, or of aërial acid, according to the degree, in which the calx has been dephlogisticated. It has been already observed, that saccharine matter cannot be brought to ferment without water.*

5. A vinous liquor, on distillation, yields an ardent spirit.

6. Spirit of wine has had the whole of its inflammable part dissipated by combustion; after which, Mr. Lavoisier found the watery part increased in weight, from sixteen to eighteen ounces, by the absorption of the air, decomposed by the combustion.

7. The residuum, after the distillation of ardent spirit from fermented liquors, is *acid*.

8. Mr. Lavoisier has supposed pure air to be the acidifying principle of all the acids; and that their difference, from each other, consists in the basis united to this pure air.

As our experiments were made with an infusion of malt, and with fixed air, employed as a ferment, let us endeavour to account for the several phænomena and results of fermentation, as appearing in these experiments.

* More recent experiments having rendered the facts, contained under this article, more doubtful than they appeared to be, at the time this paper was first published; and the inferences, deduced from them, not being altogether satisfactory to the Author's mind, he has withdrawn them in the subsequent part of the Essay.

The wort being impregnated with fixed air, and placed in such a situation, as to bring it to the degree of heat, at which wort is commonly mixed with yeast, the gas, for some time remains in a latent, or quiescent state; but, from its tendency to recover its elastic form, aided by heat, it presently begins to burst from the bonds in which it was confined. By this effort, the mucilaginous parts of the infusion are attenuated; the saccharine matter is developed; and, the same cause, continuing to act, the constituent parts of that matter are separated, and, the particles of the component principles, being by this means placed beyond the sphere of their mutual attraction, begin to repel each other. A large quantity of phlogiston is discharged, together with some pure air. The greatest part of the inflammable principle enters into a new combination, joining the basis of the vegetable acid, while another, but much smaller portion, uniting, in its nascent state, with the pure air, forms fixed air; which, in its attempt to escape, carries up with it much of its viscid confinement. In the conversion of the pure into fixed air, a considerable portion of heat is rendered sensible. And this heat contributes to the farther decomposition of the saccharine substance. The viscid matter, collecting on the surface, prevents the escape of too much of the gas, and promotes its reabsorption, that, thereby, the brisk and agreeable taste of the liquor

liquor may be formed; and that this gas may contribute, in a future stage of fermentation, to the constitution of the acetous acid.

The vessel being stopped, some of the saccharine matter, being not decomposed, the liquor will continue to have a sweetish taste. But, the fermentation still going on, in a more gradual manner, the liquor will become less sweet, and, proportionably, more impregnated with ardent spirit; and the *fæculæ* subsiding in the form of lees, it will be now fully fermented, mellow, and pellucid.*

But, if the saccharine matter be too much diluted, or the vessel be placed in a warm situation, the liquor will then pass from the vinous, to the acetous, fermentation.

In the formation of the saccharine acid, by means of nitrous acid; the last is supposed, by carrying off the phlogiston of the sugar, to develope the saccharine acid. Or, according to Mr. Lavoisier's hypothesis, one of the constituent parts of the nitrous acid performs this office, while the other, or pure air, uniting to the peculiar basis, contained in the sugar, forms saccharine acid.

* In the fermentation of wine a substance is deposited at the sides and bottom of the cask called tartar; which is lately discovered to consist of pure vegetable alkali, united to a superabundant quantity of a peculiar acid. But as this is not produced by malt liquors, it has not been noticed in the essay.

So in the acetous fermentation, if it happen that the phlogiston is not in sufficient quantity, or the force with which it is combined in the liquor be weakened, by a long application of heat or other causes; it will begin to separate from the basis of the vegetable acid, and the ardent spirit will be decomposed, and in proportion as the inflammable principle is separated, the basis, now left at liberty, will unite with the fixed air, and the result will be acetous acid. It is probable also that during the progress of the acetous fermentation, an absorption of pure air from the atmosphere, takes place.

Thus the acetous fermentation acts in a manner, in some respects, analogous to the action of nitrous acid on sugar. In the latter case, the phlogiston is separated more rapidly, but imperfectly; and the acid, resulting from the process, is that called saccharine acid. In the former, the changes are more slowly produced; the phlogiston flies off more gradually; but the same cause continuing to operate, the dephlogistication is more complete than in the other case, and vinegar is produced. And perhaps it may serve to give some appearance of probability to the above theory, to recollect, that the residuum of fermented liquors, after the separation of the ardent spirit, which appears to be water supersaturated with phlogiston, is *acid*.* I have

* In the former edition of these Memoirs, I had supposed a decomposition of the water employed to take place, and that

I have avoided carrying these reflections to the phænomena which appear in the putrid fermentation, as not so immediately connected with saccharine substances; and from a conviction that I have already engrossed too much of the Society's time.—If I have contributed any thing to their entertainment, or that may tend to enlarge the bounds of science, I shall esteem myself happy; and, more so, if what has been advanced may prove useful and advantageous to my fellow-creatures.—Sensible that one such fact is of more real worth, than the most ingenious and well-wrought hypothesis.

that it was resolved into the two constituent parts, viz. pure, and inflammable air, of which it has been imagined, by Mr. Lavoisier, and others, to be formed. But notwithstanding a late experiment, made by this ingenious philosopher, the result of which seems favourable to my hypothesis, I had, for various reasons, relinquished this part of it, before I had the pleasure of perusing Mr. Rigby's Chemical Observations on Sugar, which contain some very candid and weighty objections to the doctrine. Among these Mr. Rigby remarks, that it never has been proved that water does consist of pure and inflammable air, and since the publication of his Treatise, the evidence against the presumption is become strong by Dr. Priestley's late Experiments, by which it appears, that the water, produced in the explosion of these airs, is not a new compound, from a union of the two, but a separation of the water previously contained in them. The degree of heat, Mr. Rigby observes, seems inadequate to the supposed effect, but fermentation in many instances, which might be adduced, brings on by slow degrees, changes similar to those effected, more instantaneously, by the action of heat.

On the ORIGIN of ALPHABETICAL CHARACTERS.

*By GILBERT WAKEFIELD, B. A. late Fellow of
Jesus College, Cambridge. Read March 10, 1784. **

AT this period of time, when the human mind has acquired so much honour by the introduction of such astonishing improvements, into the various departments of philosophy and science, beyond the example of former ages; those speculations, which tend to aggrandize the dignity of reason, are received with avidity, and admitted with a readier acquiescence. We are apt to conclude, that the same ingenuity and strength of faculties, which have been able to investigate the sublime laws of the planetary system, to adjust the tides, to

* The unsettled situation of the author, and his absence from books, would not suffer him to discuss the following subject in any other than a popular manner. The most satisfactory authorities, however, might be produced for every assertion of importance, and much more might have been alledged to the purpose of the question. But the reader must condescend to take the attempt, as it is offered to his notice. With respect to the *Armenian* language, with which the author is not acquainted, it is said to be of more modern date, than the other oriental tongues, and to have a great affinity to the *Greek*.

disentangle

disentangle the rays of light, to detect the electric fluid, and to extend their researches into the remotest regions of mathematic science; must be adequate to any attainments, and discoveries whatsoever. Nor has any disputable topic of enquiry been accepted more implicitly of late, even by men accustomed to hesitate and to examine, than the gradual discovery of *Alphabetical Characters* by the successive exertions and accumulated experience of mankind—To call in question a maxim so generally believed, may appear, in the judgement of philosophers, to favour of superstition and credulity: but, perhaps, it will be found, that the evidence in favour of this maxim, bears no proportion to the confidence, with which it is embraced. As a man, I rejoice in whatever is honourable to our nature: but various scruples have ever forbidden my assent to this popular article of belief. I will state my objections to it in a plain and popular manner with all possible perspicuity and conciseness; and then submit the determination of this question to the judgement and candour of this audience.

I. The five first books of the *Old Testament* are, I believe, acknowledged by all to be, not only the most ancient compositions, but also, the most early specimens of *Alphabetical Writing*, at present existing in the world. Now, if alphabetical writing be indeed the result of

human ingenuity, one great peculiarity distinguishes it from all other *human inventions* whatsoever: the very first effort brought it to perfection. All the sagacity and experience of succeeding generations, illustrated as they have been by a vast influx of additional knowledge, beyond the most accomplished of their predecessors, have been unable to superinduce any real improvement upon the *Hebrew* alphabet. This seems to me a singularity utterly irreconcilable to the common hypothesis: at least, I am acquainted with no plausible answer to this objection.

Should any one reply, “ that *alphabetical*
 “ *characters* may have been in existence many ages
 “ prior to the date of these specimens in the
 “ Scriptures, but that the more ancient memori-
 “ als, in which they were exhibited, have perished
 “ by the desolations of ignorance and the vicissi-
 “ tudes of time ;” I must demur at an argument
 that advances no premises of sufficient validity to
 authenticate this conclusion. For, 1. It is mere
affirmation, without the least shadow of historical
 testimony to give it countenance. 2. To wave
 the authority of the *Jewish* scriptures upon this
 point; (which, however, I must beg leave to
 observe, is corroborated by abundant evidence
 from philosophy and experience, as well as history)
 that simplicity of manners, predominant in the
 early ages, so observable in the accounts delivered
 down

down by sacred and profane historians; the confessed mediocrity of their intellectual acquirements, and the confined intercourse of nations with each other, which would render such an expedient less necessary, and therefore less likely to be discovered: all these considerations seem to argue with no little cogency, that so complex, so curious, so wonderful, so consummate a devise as that of *alphabetical writing* could hardly be *first* detected by a race of men, whose wants were few, whose advantages were circumscribed, and whose ideas were commensurate to their situation. This position, therefore, conjectural as it is, and unsubstantial, seems unworthy of further animadversion.

11. If *alphabetical writing* were a *human invention*, the natural result of ingenuity and experience; might we not expect, that different nations, would have fallen upon the same expedient, independently of each other, during the compass of so many ages: when the faculties of the mind are equally capable at all times, and in every corner of the universe, and when the habits of life and modes of thought inevitably bear so great a resemblance to each other in similar stages of society? This I say, were but a reasonable expectation: which however, corresponds not to the event. For *alphabetical writing*, as now practised by every people in the universe, may be referred to *one* common original. If
this

this proposition can be proved, the argument from successive derivation, without a single instance of independent discovery, must be allowed to amount to the very highest degree of probability in my favour: and the common supposition will appear perfectly gratuitous, with the incumbrance also of this great paradox: “ you tell us, I might say, of an invention, “ which is the regular consequence of refinement “ in society, nothing more than a gradual advancement from what is plain to what is “ complex; by a similar process, pursued by the “ mind in all its exertions for improvement: and “ yet, we can perceive no reason to conclude, “ that any community but one, and that in no “ wise distinguished by any vast superiority of “ inventive genius, or the improvements introduced by them into common life, ever compassed this discovery; though the human “ powers have been uniformly the same, and the “ conduct of society has been greatly similar in “ different nations at different periods of time.”

Let us consider then, how the evidence stands in this case: only premising, that, where a continuity of transmission appears to have taken place, arising from the intercourse of nations with each other; and where the words are the same, the grammatical construction, and other minute peculiarities of composition much alike, in two languages; these languages are of the
same

same texture: and that *alphabetical composition*, attended by these circumstances of resemblance, must flow from one source: especially, if the difference in the *alphabetical marks* of these two languages should be no objection, but may be accounted for upon reasonable principles.

It will be readily allowed then, I presume, that no modern *European* nation, exclusive of the *Turkish* empire indebted to the *Greeks* and *Arabians*, separately invented *alphabetical writing*: we all derived, without any doubt, this art from the *Romans*. The *Romans* never laid claim to the discovery: they ascribed all their literary advantages to the *Greeks*. This accomplished people acknowledge, with one voice, to have received the art from the *Phœnicians*; who, as well as their colonists the *Carthaginians*, are known by the learned to have spoken the *Hebrew* language, or a dialect scarcely varying from the original. The *Coptic*, or *Ægyptian*, wears the exactest resemblance in the majority of its characters to the *Greek*; they, therefore, must be referred in all reason to the same origin. The *Chaldee*, *Syriac*, and later *Samaritan*, are dialects of the *Hebrew*, without any considerable deviation, or many additional words. The *Æthiopic* differs more from the *Hebrew*, but still less than the *Arabic*. These languages, however, notwithstanding such deviations, have issued from the same stock; as the similarity of their formation,
and

and the numberless words, common to them all, demonstrably evince: and the *Persic* has a close affinity to the *Arabic*. Alterations would naturally be introduced, proportionate to the civilization of the several possessors, and their separation from the other nations: and this will account for the superior copiousness of some above the rest. So then, not to determine which was the more ancient language, the *Hebrew*, *Syriac*, or *Arabic*, a question of no importance on this occasion; all the languages in use amongst men, that have been conveyed in *alphabetical characters*, have been the languages of people, connected ultimately or immediately, with those, who have handed down the earliest specimens of writing to posterity. And when the languages of the *Eastern* nations are so similar—when so curious an art would be, in all probability, the first improvement communicated by one people to another—is it not morally certain, that *alphabetical writing* originally centered in one people? For length of time has deprived us of express historical testimony in this case.

Indeed, this proposition seems to be sufficiently ascertained by another argument; that is from the sameness of the artificial denominations of the letters in the *Oriental*, *Greek*, and *Latin* languages; accompanied too by a similar arrangement: *Alpha*, *Beta*, and so on.

But

But in opposition to this evidence, some will argue against all possible admission of our conclusion, by alledging the entire dissimilarity of characters employed by the ancients to discriminate their letters. “Why should not one nation, it will be urged, adopt from the other the mode of expressing the art, as well as the art itself? To what purpose the trouble of inventing another system of *characters*?”

Various answers may be returned to this objection.

1. We know, from the instance of our own language, what diversities may be introduced in this respect merely by length of time, and an intercourse with neighbouring nations. And such an effect would be much more likely to take place, before the art of printing had contributed to establish an uniformity of character. For, when every work was transcribed by the hand, we may easily imagine how many variations would arise from the fancy of the scribe, and the mode of writing so constantly different in individuals. What *two* persons write without the plainest symptoms of peculiarity?

2. Vanity might sometimes give occasion to this diversity. When an individual of another community had become acquainted with this wonderful artifice, he might endeavour to recommend himself to his own people, as the deviser of it: and, to evade detection, might have recourse

course to the substitution of new symbols. But let no more credit be given to this conjecture than it deserves.

3. The characters of the *alphabet* might, sometimes, be accommodated, as much as possible, to the symbolical marks already in use amongst a particular people. These having acquired a high degree of sanctity, by the use of many generations, would not be easily superseded, without the aid of some such contrivance, by an adventitious practice.

4. But I have more than conjecture to offer in support of this argument; even the testimony of an ancient historian: whose account will serve as a general evidence in this case, and may lead us to conclude, that similar deviations may have taken place, amongst other classes of men, as well as in that instance, which he particularly specifies from his own knowledge.

Herodotus, in one part of his history, has the following relation:

“ Those *Phœnicians*, who came with Cadmus,
 “ introduced many improvements among the
 “ *Greeks*, and *alphabetical writing* too, not known
 “ in my opinion, to the *Greeks* before that period.
 “ At first they used the *Phœnician* character: but
 “ in process of time, as the pronunciation altered,
 “ the standard of the letters was also changed.
 “ The *Icnian Greeks* inhabited at that time the
 “ parts adjacent to Phœnicia: who, having
 “ received

“ceived the art of *alphabetical writing* from the
“*Phœnicians*, used it, with an alteration of some
“few characters: and confessed ingenuously, that
“it was called *Phœnician*, from the introducers
“of it. And I have seen myself the characters
“of *Cadmus* in the temple of *Ismenian Apollo* at
“*Thebes* in *Bœotia*, engraven upon tripods, and
“very much resembling the *Ionian* characters.”

5. The old *Samaritan* is precisely the same as the *Hebrew* language: and the *Samaritan Pentateuch* does not vary by a single letter in *twenty* words from the *Hebrew*. But the characters are widely different: for the Jews adopt the *Chaldaic* letters, during their captivity at *Babylon*, instead of the characters of their forefathers. This difficulty then seems to have been sufficiently considered.

III. What we know of those nations, who have continued for many centuries unconnected with the rest of the world, strongly militates against the hypothesis of the human invention of *alphabetical writing*. The experiment has been fairly made upon the ingenuity of mankind for a longer period, than that which is supposed to have produced *alphabetical writing* by regular gradations: and this experiment determines peremptorily in our favour.

The *Chinese*, a people famous for their discoveries and mechanical turn of genius, have made some advances towards the delineation
of

of their ideas by arbitrary signs; but have nevertheless been unable to accomplish this exquisite device: and after so long a trial, to no purpose, we may reasonably infer, that their mode of writing, which is growing more intricate and voluminous every day, would never terminate in so clear, so comparatively simple, an expedient, as that of *alphabetical characters*.

The *Mexicans*, also, on the new Continent, had made some rude attempts of the same kind, but with less success than the *Chinese*.

We know also, that *Hieroglyphics* were in use, among the *Ægyptians*, posterior to the practice of *alphabetical writing* by the *Jews*: but whether the *Epistolography*, as it is called, of the former people which was in vogue, during the continuance of *Hieroglyphics*, might not possibly be another name for *alphabetical writing*, I will not take upon me to decide.

Now what will our adversaries reply to this? They will pertinaciously maintain, that *alphabetical writing* is a *human invention*: and yet all those nations, who have been conversant with this expedient, are discovered to have derived it from the same original, from some one people in the *East*, whose means of attaining it we cannot now find out; but are compelled to conclude from analogy, and the experience of other nations, that their imagination, as it was not more fertile, was not more successful, than that of their neighbours.

Again:

Again: Where large communities have flourished for ages, but unconnected with those countries, which enjoyed this advantage, their own solitary exertions were never capable of effecting this capital discovery. Is it possible for presumptive evidence to be more satisfactory than this?

IV. Lastly, We will consider the argument, upon which the commonly received supposition entirely depends: that is, the natural gradation through the several species of symbols, acknowledged to have been in use with various people, terminating, at last, by an easy transition, in the detection of *alphabetical characters*. I cannot see this regularity of process, this ease of transition, so clearly as some others appear to do; but let every one determine for himself from the contemplation of the several stages of emblematical representation.

1. The first method of embodying ideas, would be, by drawing a representation of the objects themselves. The imperfection of this method is very obvious, both on account of its tediousness, and its inability of going, beyond external appearances, to the abstract ideas of the mind.

2. The next method would be somewhat more general, and would substitute two or three principal circumstances for the whole transaction. So two kings, for example, engaging each other with military weapons, might serve to convey

the idea of a war between two nations. This abbreviated method would be more expeditious than the former: but what it gained in conciseness, it would lose in perspicuity. The great desideratum would still be unachieved. This is only a description, more compendious indeed, but still a description, of outward objects alone by drawing their resemblance. To this head, if I mistake not, the *picture writing* of the *Mexicans* is to be referred.

3. The next advance would be, to the use of symbols: the incorporation, as it were, of abstract and complex ideas in figures more or less generalized, in proportion to the improvement of it. Thus, in the earlier stages of this device, a *circle* might serve to express the *sun*, a *semicircle* the *moon*: which is only a contraction of the foregoing method. This *symbol writing* in its advanced state would become more refined, but ænigmatical and mysterious in proportion to its refinement. Hence it would become less fit for common use, and therefore, more particularly appropriated to the mysteries of philosophy and religion. Thus *two feet*, standing upon water, served to express an *impossibility*: a *serpent* denoted the oblique trajectories of the heavenly bodies: and the *beetle*, on account of some supposed properties of that insect, served to represent the *sun*. Of this nature were the *Hieroglyphics* of the *Ægyptians*.

4. But

4. But this method, being too subtle and complicated for common use, the only plan to be pursued, was a reduction of the first stage of the preceding method. Thus a *dot*, instead of a *circle*, might stand for the *sun*: and a similar abbreviation might be extended to all the symbols. Upon this scheme, every object and every idea would have its appropriated mark: these marks, therefore, would have a multiplicity commensurate to the works of nature, and the operations of the mind. This method also was practised by the *Ægyptians*, but has received its highest perfection from the *Chinese*. Their vocabulary is consequently interminable, and almost infinite: so that the longest life is said to be incompetent to a complete acquaintance with it: and who does not see, that it may be extended to any assignable point whatever? Now, if we compare this amazingly tedious, and cumbersome, and prolix contrivance, with the astonishing brevity and perspicuity of *alphabetical writing*, we must be persuaded, that no two things can readily be conceived more dissimilar; and that the transition, from a scheme constantly enlarging itself and growing daily more intricate, to an expression of every possible idea by the modified arrangement of *four* and *twenty* marks, is not so very easy and perceptible, as some have imagined. Indeed, this seems to be still rather an expression of things by

correlative characters, like the second stage of symbol writing, than the notification of ideas by arbitrary signs. But, perhaps, we are not so intimately acquainted with the *Chinese* method, as will justify any conclusions from it respecting this subject. We know, however, that it is widely different from the art of *alphabetical writing*, and infinitely inferior to it.

Till these objections, to the *human invention* of *alphabetical characters*, are refuted, there will be no reason, I apprehend, to treat a different supposition from that generally admitted, as chimerical, and destitute of philosophical propriety.

I will finish this imperfect dissertation by two or three remarks relating to the subject.

1. *Pliny* asserts the use of letters to have been eternal. This shews the antiquity of the practice to extend beyond the æra of authentic history.

2. The caballistical doctors of the *Jews* maintain, that *alphabetical writing* was one of the *ten* things, which God created on the evening of the sabbath.

3. Most of the profane authors of antiquity ascribe the first use of *alphabetical characters* to the *Ægyptians*; who, according to some, received the expedient from *Mercury*; and according to others, from the God *Teuth*.

4. Is there any reason to suppose, from the *history* of the *human mind*, that *oral language*,
which

which has been long perfect, beyond any memoirs of our species in heathen writers, and is coæval with man, according to the testimony of scripture: is there any reason, I say, to suppose, that even *language itself* is the effect of *human ingenuity and experience*?

An ESSAY on CRIMES and PUNISHMENTS. By the
Rev. WILLIAM TURNER. Read March 24,
1784.

FROM the original imperfection of Human Nature in general, and the different opportunities and talents of individual men, imperfect and different judgments will necessarily arise, some of which, at least, must consequently be errors. These will lead to the formation of different dispositions and habits; of which, those founded on right reason, and a proper judgment of things, must be good, while those founded on error, and a perverted judgment of things, must, in that proportion, be depraved. These different dispositions will lead to correspondent actions, which will be good or bad likewise; and, as far as they are the one or the other, will be proportionably useful or detrimental, to the

authors of them, and to the society of which they are members.

Since, then, our errors may produce so important effects to ourselves, and those with whom we are concerned, it is of the greatest consequence that we should early correct all such as may lead to hurtful actions. This will be best effected, by considering attentively our various relations with respect to other beings, the advantages we derive from such relations, and the duties incumbent upon us in consequence of them.

Now we shall find, that when man was first created, he was placed in a world so constituted, as that, by the practice of certain personal and relative duties, he might best promote his own happiness, and that of his fellow-creatures. He was thus made subject to a moral law, engraven, as it were, upon his mind, for the due observance of which he was left accountable to his Almighty Creator. But in process of time, as mankind multiplied upon the earth, and violations of this original rule of action increased continually in frequency and enormity, it became necessary for men to unite together, in distinct and separate bodies, for mutual protection and defence: and hence would arise the first forms of civil society.

Thus we find, that the human race are subject and accountable to a moral, and a political law.

At the head of the one, is the great U
things, as the supreme eternal Leg
Executor. At the head of the other,
civil governors, who are appointed to
these important offices in those tempora
ties, into which men enter during thei
nuance in this world.

Each of these constitutions of governm
attended with many advantages, the one pro
ting our moral, the other our political happine

With respect to the former, however, the eter
nal laws of moral obligation, with the different
degrees of moral enormity, are so deeply engraven
on the human mind by nature, and so forcibly
republished in the books of revelation, that they
seem not so much the objects of speculative dis
quisition: every good man is sensible of their
obligation, and of the proper restrictions with
which they are to be taken. But an attention to
the rules by which actions are estimated in a
political view, is highly necessary for all men,
whatever be their moral character; since other
wise, they may be misled by the idea, that the
same general rules obtain both in the divine and
human governments, under the political as well
as the moral constitution; so that, if they be care
ful to keep within the bounds of strict morality,
they can never become amenable to the laws of
civil society *. This, however, is, doubtless, an

* Compare Judge Forster's preface to his Reports,
quoted in the last page of this essay.

I appear from the former part of the Essay, the proposed object of which is, to point out the difference between civil and political transgressions, with their respective punishments: so far, at least, as may serve to form some idea of the rules which a legislator should observe, in his attempts to remove the disorders of society: And,

Secondly, To offer some remarks on the proportion of punishments to offences; and to enquire into the right, utility, and success, of *severe* civil institutions, particularly of capital punishments.

As we have divided transgressions, so we may distinguish punishments, into moral and political, and with respect to each of these may consider, the *end*, the *subjects*, the *nature*, and the *measure*, of punishments.

I. The *end* of *all* punishment seems to be the same, viz. the prevention of future crimes; which is effected, either by reforming or tying up the hands of the offender himself, or by deterring others from the imitation of his example. This is the only ground upon which punishment can well be justified; for barely causing the offender to suffer, without producing any further effect, besides that it is no proper satisfaction, seems to imply too much of a spirit of revenge or malice; which we cannot, without blasphemy, suppose to actuate the Divine Being, and which is disclaimed by every earthly judicature.

II. But

II. But in the *subjects* of punishment we shall find a much greater disagreement; and indeed the *purposes* of moral and political government are so different, that we may naturally expect it. The purpose of the former is, *to train up rational beings to the highest moral perfection*; moral actions, therefore, alone, must be subject to its laws, which are calculated to obtain their end, by holding out rewards for actions proceeding from a good principle, and punishments for those which arise from a bad one. The purpose of human governments, on the other hand, is merely *the preservation of its various advantages to the several individuals of the state*; and therefore, those actions which tend to interrupt the enjoyment of these advantages, by disturbing the peace and good order of society, are the *only* subjects of human laws.

This distinction also necessarily arises from the different powers of the judges, as well as from the different ends of the institutions. For since all things are open to the Deity, so that he can discover not only the actions, but even the most secret thoughts of men, he is a proper judge with respect to the spring or principle of any action. But since the wisest human legislator cannot undertake to determine, with certainty, the motives which have led to the performance of any action, he must not pretend to punish according to their moral enormity; but he is an adequate judge of the political benefit or harm

harm to be expected from any particular action, or general course of conduct; and may therefore justly restrain and punish all such as he is convinced are inconsistent with the peace of that society over which he presides, without enquiring whether they proceed from a good or bad moral principle. The infatuated murderer of the Duke of Buckingham was probably influenced by the best motives to the commission of such an offence; but whether this was actually the case or not, nay, though the magistrate had been fully persuaded that it was, he would not therefore have been justified in acquitting him, since he would by that means have afforded an opportunity for every murderer (nay indeed for any offender) to plead the same excuse; which, as no plea of this kind can with certainty be contradicted, would make way for the introduction of every kind of licentiousness, and quickly bring on the total overthrow of civil society. He was therefore obliged, whatever his private opinion might be, to punish the delinquent *as guilty of an offence against the laws of his country*; and as for the rest, must content himself with the reflection, that it is in the power of the Divine Being hereafter to ratify or revoke his sentence; to reward Felton, as a lover of his country; or to recompense Villiers, for the misfortune he suffered as the devoted victim of blind party-rage.

We may from hence infer, by the way, that the *opinions* of men cannot, with propriety, come under civil jurisdiction; every man being accountable, in this respect, to his moral governors only, his conscience and his God. It is time enough for the civil magistrate to interpose, when opinions manifest themselves in the conduct * of those who profess them; and then, if the actions they occasion are hurtful to society, he has a right to restrain *them*, without troubling himself to enquire (because he cannot determine) whether the principles which gave rise to them are true or false.

We may also remark, in a cursory manner, that this view of human punishments furnishes a strong presumptive evidence in favour of the doctrine of a future retribution, in which, all the apparent injustice of more imperfect courts will be rectified, and a society be established, whose interests will be more closely connected with the strictest principles of virtue. And though we should allow, to those who contend for it, that the *natural* arguments for a future state are not sufficient of themselves to afford full conviction of its certainty, yet when, since the promulgation of Christianity, we are convinced of it by another kind of evidence, it is not, surely, degrading Divine Revelation, to shew that its doctrines are consistent with right reason; since

* Pudsey-Ordination-Service, Q. III. p. 60.

both are the gift of the same Almighty Being, from whom contradictions cannot arise.

III. We are now come to the *nature* of punishment. Concerning the nature of those punishments which will be inflicted by the Deity in consequence of immoral actions, it is impossible for us to determine, in what they differ from human punishments, and how far they extend. Only we may conjecture, that, as the moral government of the Deity is of a spiritual or mental nature, the punishments also will probably be mental; and may possibly exist as long as their subject, the mind. Human governments, on the other hand, being entirely of a temporary nature, the punishments they provide must be temporary also; such as may either *produce an amendment in the offender himself*, by laying before him such motives as may be sufficient to deter him from a repetition of his crime, or place him in such a situation, as shall take away from him all opportunity of doing further mischief. The first of these classes comprehends *fines, corporal punishments, imprisonment for a limited time, and temporary banishment*; the second class includes *perpetual imprisonment, or exile, and death*.

It is obvious that these sanctions carry with them different degrees of severity: which leads us to enquire into.

IV. The *rule or measure* of punishment.

The general rule of all punishments is, that
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the severity be proportioned to the enormity of the crime. But the difference between ethical and political virtue (if such an expression may be allowed) is no where more apparent, than in this article. The term enormity, when applied to crimes committed against the laws of morality, signifies the *moral depravity* of the action, which is diminished by any temptations there may be to commit it; since, as it requires greater fortitude to refrain from the commission of a crime, when it is recommended by numberless temptations, so these furnish an apology for the person, who has been so unfortunate as to yield to them. The *frequency* of the crime, particularly, operating as a temptation, furnishes an especial excuse for its commission. And in like manner, all other circumstances, which may tend to induce a man to commit any given offence, act like negative quantities in arithmetic, tending to diminish the sum of enormity, and consequently to lessen the punishment.

But when any actions are considered as offences against human laws, the term enormity is not used in a moral sense, but signifies *the degree of detriment any particular action may occasion to the state*. And, by this rule, actions, in themselves of little or no moral turpitude, may be punished with the greatest severity, as is frequently the case with the crime of high treason; while, on the other hand, the vilest and most complicated
acts.

acts of villainy, may, through a necessary defect of foresight in the legislator, not only pass unpunished, but even, in some cases, be rewarded. I am enabled to produce a case, which will greatly illustrate what has been said: it comes from an authority, which will readily be acknowledged to be unquestionable.* In one of the midland counties of England, not many years ago, an unnatural son hired a bravo to murder his father. In consequence of the old man's death, a proclamation was issued out, offering a reward to any one who would discover the offender, and a pardon to any accomplice *who was not the immediate murderer*. The son informed against the person whom he had himself hired, and, upon his conviction and execution, claimed and obtained the pardon and the reward. Now we cannot, if we wished it, conceive a more glaring instance of moral depravity; and yet, by human laws properly constituted, this most atrocious of all persons was not only indemnified, but rewarded, for that very action, in which his villainy was most eminently apparent.

In this view of the term, the *frequency* of any crime increases, instead of lessening, its enormity.

* Dr. Aikin (a man never to be mentioned by his pupils but with gratitude and veneration) produced this instance in his Ethical Lectures, as a case which happened in Leicestershire, during his residence at Kibworth.

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For all crimes being hurtful to the state, their frequent commission ought to be carefully prevented, and the increase of them is an alarming symptom of political decline. When, therefore, any crime is often repeated, its punishment must increase accordingly, in order to counterbalance the additional temptation, which its general commission might otherwise occasion. Thus in the year 1748, his late Majesty issued a proclamation, setting forth, that in consequence of the great frequency of high-way and street-robberies, he would pardon no person convicted of this crime for the space of a year to come; which was, in effect, an increase of punishment, as it took away the chance of escaping.*

For the same reason, all other temptations to the commission of crimes, are to be counterbalanced by such additional punishments, as may furnish sufficient motives to refrain from them. Among these temptations, *difficulty of detection* is one of the most powerful,† and is on that account most generally and strictly guarded against. Thus, in cloathing countries, to cut off, and take away a *part* of a piece from the tenter-hooks is a *capital* offence; but to steal the *whole* piece only subjects the delinquent to

* A similar measure was pursued, in the year 1783, with respect to robberies attended with murder, or cruel usage.

† See the note on footpads, page 323.

the punishment of *transportation*. The reason of this is, that if the whole piece be taken, it may easily be known by the marks of the maker, but if the piece be cut, the marks are lost, and the theft cannot be so easily discovered. And this principle was formerly carried so far in the Isle of Man, as Judge Blackstone informs us, * that “stealing a horse or a cow was only “prosecuted as a trespass, on account of the “difficulty of conveying them out of the island, or “of secreting them in that small territory; while “stealing a pig or a fowl was made a capital “crime, as so small an animal might easily “be devoured or concealed.” This last instance is adduced, only to shew how far a principle which is good, when moderately applied, may be stretched into absurd severity.

Thus we see, that whereas the frequency of any crime, and the other temptations to its commission, *lessen* its *moral* enormity, and consequently diminish its punishment; these circumstances, on the other hand, *increase* the *political* enormity of an offence, and consequently increase the punishment also.

At the same time, it must be acknowledged, to be a very difficult part of the province of the human law-giver, so to *proportion punishments to offences*, as to keep clear, on the one hand, of

* Comm. Book IV. C. 1.

the inconveniences, of too *lax* a sanction to the laws, and to avoid, on the other, the evils of too *severe* a one.—In order to do this with exactness, it is requisite that there be previously obtained a full and perfect scale* of offences, classed according to their *political enormity*,† which perhaps is impossible; and we must afterwards be able to apply the several kinds of punishment which it is in the power of the civil magistrate to inflict,‡ in a due proportion to the *degrees* of enormity marked down in the scale. He who approaches nearest to this ideal perfection, is the wisest and most perfect legislator: he who falls short of it, must, in that degree, labour under great disadvantages.

For if the *evil consequences* of the punishment he appoints be less than the *probable advantages* of the crime it is meant to restrain, it will, in effect, be worse than no punishment at all; for then, what is gained by the crime, is gained not only securely, but *legally*. The article of smuggling will afford us a striking example. The *political enormity* of this offence seems not to have been sufficiently attended to. || It ought to be remembered, that other offences, without the

* Beccaria, C. VI.

† See above, I. 4.

‡ See above, I. 3.

|| Except by Dr. Franklin. See his admirable paper on smuggling in his Miscellaneous Pieces.

exception even of murder, *immediately* affect *individuals* only; whereas, in this case, an immediate, open, and violent attack is made upon the property of the whole community, by endeavouring to defraud the state of those duties, which make a part of its just revenues. One should therefore expect, that even the severest punishment would be provided against a crime, of this nature: whereas we find, that all the ill consequence that generally arises to the offender, is the seizure of those goods, the duty upon which he thus illegally avoids the payment of; * and, in some cases, a small pecuniary fine. Now if it be a chance of six, or ten to one, that such a seizure will not be made, is this sufficient to *deter*, nay is it not enough to *encourage* the smug-

* This Judge Blackstone asserts (I. p. 317.) is the only natural and reasonable punishment for smuggling; but at the same time laments its inefficacy, and the necessity of greater severity, in order to the restraint of a crime, "which, says he, is no natural, but merely a positive offence." But if this were a sufficient reason for lenity in the case of *smuggling*, it would be so likewise for *high-treason*. This admirable writer seems not to have attended to the distinction between moral and political enormity.

If it be objected, that all *forcible* acts of smuggling, resistance to custom-house officers, &c. are declared by 19th Geo. II. C. 34. to be *felony*, it may be replied, that other crimes are here involved with smuggling; of which *shooting at*, or *murdering*, any one, is felony by itself; and resistance to the officers appointed to execute the laws, is a kind of treason. So that it is not smuggling, but *murder* and *treason*, that are punished by this statute.

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gler to persist in, a practice so highly detrimental to society?

If, on the contrary, the punishment be too severe, as is the case, at least, whenever it is more than adequate to the prevention of the crime, the following pernicious consequences must necessarily ensue.

1. As human punishments cannot rise beyond a certain height, if the severer ones begin to be inflicted too low in the scale of offences, the highest punishments will be brought into use long before we reach the highest offence; the necessary consequence of which must be, that crimes of different degrees of enormity will be punished equally. From hence it will as necessarily follow, that such crimes will be looked upon as indifferent with respect to each other. Habitual offenders are accustomed to estimate crimes by their consequences, and not by their moral turpitude: whenever, therefore, the civil magistrate makes no difference between the *punishment*, they will be apt to make as little difference between the *commission*, of one, two, or more of them; according as it may suit their present convenience, or occasion less danger of detection.* Thus, if both robbery and murder

* Can there be a better reason given, why footpads more frequently accompany their depredations with cruelty than highwaymen on horseback, than that, as they are more easily pursued, it is their business to render the sufferers incapable of pursuit?

are punished equally, the highwayman will naturally argue with himself thus: "I shall be liable to the same punishment whether I rob this man, or whether I rob and murder him too; but if I rob him only, I leave an informer, who will endeavour to bring me to justice; my safest way, therefore, is to put an end to him at once, and so place an effectual bar to all information, at least from that quarter." This is the reason which Judge Blackstone assigns, though there may probably be others, why in France they seldom rob but they murder also, whereas in China, where murderers only are cut to pieces, they often rob, but never murder.* And he at the same time answers the question "why does not this principle operate in England, as well as in other countries?" by shewing, that though the same punishment is provided both for robbery and murder, yet the robber has many chances of escaping, while the murderer is almost sure of having his sentence strictly executed: besides that a difference is made, both in the expedition and solemnity of the execution, and in the subsequent disposal of the body.

2. Again, if the same punishment must serve for different crimes, and the highest punishment is an adequate satisfaction for the highest crime,

* Comm. B. IV. C. 1. p. 18.

for many crimes it must be *more* than a satisfaction, and therefore worse, that is, more detrimental to society, than the crime itself. The laws of Draco, we are told, were made on a different principle: he conceived *that the least offences merited death*, and he could find no greater punishment for the highest. But however those divines may determine on this subject, who contend, *that every sin, being an offence against an infinite being, is deserving of an infinite and eternal punishment*;* yet certainly no politician will admit this law-giver's principle. And we need not wonder that his dreadful code, emphatically, but properly said to have been *written in blood*, was not suffered to continue long in force.

But this evil is of still greater consequence, as it leads to another of much more fatal tendency. For,

3. The too great severity of punishments *hinders the execution of the laws*, especially of those which have for their object crimes of a less atrocious nature. In this case, † either the party injured is induced to neglect a prosecution, rather than cause the delinquents to be so heavily punished; or, if he brought to a trial, the jury

* Is it not at least as plausible to say, that every sin, being the action of a *finite* being, may be corrected by, and therefore is only deserving of, a finite and temporary punishment?

† Blackstone, B. IV. C. 1. p. 19.

are led to violate their oath, and perjure themselves to procure his acquittal; and if all this is not sufficient to save him, the judge contrives to avail himself of some palliative circumstance which may justify a respite: so that it is a pretty certain fact, that of all the criminals convicted in England upon capital indictments, scarcely one in three really suffers the punishment appointed by the laws.* Now it is wisely observed by one who well understood human nature, † and the observation is confirmed by constant experience, that crimes are more effectually prevented by the *certainty*, than by the *severity*, of their punishment. For ‡ every offender, when he reflects upon the very small proportion of convicts that really suffer for their offences, naturally encourages himself with the reflection. “Why should not I escape as well as others?”—And if, contrary to

* See the *table of executions* at the end of Howard on Prisons.

† Beccaria. C. VII.

‡ Blackstone has expressed this sentiment so much better, that I cannot resist the temptation to copy his words:

“Among so many chances of escaping, the needy and hardened offender overlooks the multitude that suffer; he boldly engages in some desperate attempt, to relieve his wants or supply his vices; and if, unexpectedly, the hand of justice overtakes him, he deems himself peculiarly unfortunate, in falling at last a sacrifice to those laws, which long impunity has taught him to contemn.”

Vol. IV. p. 19.

his

his own expectations, and to general probability, the punishment should, in the end, fall upon him, he does not so much consider it as the just recompence of his crimes, as lament his misfortune, it being marked out as the victim of an unjust and unreasonably severe institution.

Further, the severity of punishment *retards* its execution, even in the case of those who actually suffer.

Nulla unquam de *morte* hominis cunctatio longa est,

is a wise sentiment of the poet, * which may be extended to *all* severe institutions, and ought to have its due influence, as long as they continue in force: though, if it were merely on this account, all such institutions stand greatly in need of a reform. For the minds of the common people cannot easily, at such a distance of time, connect the punishment with the action that has occasioned it, and are tempted to consider an execution, when it takes place long after the offence committed by the sufferer, rather in the light of a cruel and terrible exhibition, than as the just consequence of a particular violation of the laws of society. †

These observations are intended to have a particular reference to capital punishments, which, however defended by some politicians, appear

* Juvenal.

† Blackstone, B. IV. C. 31. Vol. IV. p. 397.

to have been opposed of late by all the most respectable writers on government; * and indeed are certainly in most cases, if not universally, absurd and impolitic.

Every wise and benevolent man will consider with himself, that as life is a blessing which he cannot give, so it behoves him carefully to examine his right to take it away. He will consider, that when mankind entered into society, they only gave up such a portion of their natural liberty, and submitted to only such a measure of restraint, as was essentially necessary to secure to its members the *advantages* of society; and, therefore, that if this important end can be answered without having recourse to the punishment of death, there is no right belonging to the magistrate of inflicting such a punishment.†

* Sir Thomas More, Grotius, La Coke, Beccaria, Montesquieu, Blackstone, Voltaire.

† This seems to be a better argument than the excellent Marq. Beccaria's upon the subject, viz, "that no man
" has a right to take away his own life in a state of nature,
" and therefore cannot give up any such right to the magi-
" strate." (And Considerations on Crim. Law. p. 186.) For, admitting that no man has such a right, it must be observed, that his *right over himself*, in a state of nature, is not what he gives up, but his *right over others*, when he enters into society. And it will bear a dispute, whether a man, entirely free from controul, has not a right to estimate his loss by an injury, at what value he pleases.

Now

Now that, so far from being necessary to answer this end, capital punishments are exceedingly impolitic, and, as far as they operate, tend frequently to prevent it, the observations already made on *severe punishments in general* might be sufficient to shew.

But to these we may add, further, that the use of capital punishments argues a want of capacity in the legislator. It is rather an *expedient to get rid of* certain inconveniences in society, than an *attempt to remedy* them. It is easy enough, indeed, for the magistrate to *extirpate* mankind, but it is his business to amend them, and make them happy. "It is *quackery* in government," says Blackstone, "to apply too frequently the same universal remedy, the *ultimum supplicium* : and that magistrate must be esteemed both a weak and a cruel surgeon, who cuts off every limb, which, through ignorance or indolence, he will not attempt to cure." *

The idea of capital punishments would naturally suggest itself in the infancy of a state. When any one had committed an offence, and disturbed the peace of society, the question would then first arise "How shall we prevent these things?" And the answer most likely to occur to a set of barbarians would be, "Extirpate the offender, and give yourselves no further trouble about

* Blackstone, B. IV. C. 1. p. 17, 18.

"him."

“him.”* But, as civilization increased, it would soon be found a wiser method, to provide such expedients as might effectually induce the offender himself not to repeat his offence, deter others from its future commission, and, at the same time, preserve an useful member to society. And though I will not undertake to determine universally, that in proportion as political governments have advanced towards perfection, substitutes for capital punishments have been more frequently introduced; † yet I think it may be

* So the Hottentots have no fixed laws to direct them in the distribution of justice, and consequently, when any offence has been committed, there is no form of trial, or proportion of punishments to offences; but the *Kraul* (village) is called together, the delinquent is placed in the midst, and without further ceremony, demolished with their clubs, the chief striking the first blow.

† Feudal times will furnish us with a striking exception. Every one will acknowledge the imperfection of this form of government; and yet, under it, almost all crimes were restrained (or more properly *licensed*) by pecuniary mulcts: and few *capital* punishments were in use, except, most absurdly, for breaches of the forest law. The legislators of those days seem injudiciously to have followed, in regulating a society of which they were *properly* the governors, the example of that cotemporary hierarchy, which succeeded in its attempts to persuade mankind, that it could controul the distribution of punishments under a constitution of government, of which *its* chief directors were likely to be ranked among the most unworthy members.

be asserted with perfect safety, that government will never arrive at the perfection of which it is capable, till some very essential reform is obtained in our treatment of criminals.

And as frequent capital punishment is an argument of the want of a regular police, and a relique of barbarism in the constitution of any society, so its being still obstinately continued in use among us tends to retain among the common people those barbarous manners, from which this kind of punishment originally took its rise, and to check the progress of that humanity of spirit, which, happily for mankind, has of late been making such rapid advances in our part of the world. Let then the spirit of our punishments correspond with the spirit of the times, in order that we may sooner attain that perfection of universal charity, which ought to be the governing principle of the human mind.

Indeed the advocates for capital punishments seem now in general to be aware of the weakness

As *these* held forth a regular bill of indemnity for *sins*, with prices proportioned to their enormity; so *those* published a similar list of prices for licence to commit *crimes*: and whereas, *spiritually*, you might blaspheme against the Almighty for a trifle; so, *politically*, for a stated price, you might purchase the life of the king. A curious constitution, it must be confessed, where the *supreme magistrate* might be murdered with *safety*; but where it was *death* to shoot a *partridge*!

of their ground, and at present seldom attempt to maintain it, except in cases of murder and high treason. Perhaps in the latter case it may, sometimes, be necessary: and in the former, scripture is brought in upon us, and requires, it is asserted, the rigorous infliction of death. Now with respect to the institutions of Moses, it is to be considered, that they were made for the regulation of a very peculiar people, for very particular purposes. Their whole civil constitution seems to have been admirably adapted to the progress then made in political advancement; but to have been at the same time so contrived, as to keep them where they were, till the opening of a more perfect dispensation. All, therefore, that we can fairly conclude from the instances of capital punishments, prescribed by the law of Moses, seems to be, that such punishments are not, in their own nature, absolutely and universally, unjustifiable; for the God of nature, we may be assured, would never contradict and overthrow the established *laws* of nature. But I can no more conceive that we are obliged, in this instance, to copy the Jewish code, than that we ought to have retained the law of retaliation, * or that we are wrong in not adopting the whole scheme, without alteration, reserve, or addition.

* Ex. xxi. 24. Lev. xxiv. 20.

But

But the punishment of murder by death, it is said, does not appear to have deduced its origin or obligation from the law of Moses alone, but to have been required by the precept given to Noah and his posterity, * “Whofo
“sheddeth man’s blood, by man shall his blood
“be shed,” and consequently to be obligatory upon all the descendants of that patriarch. I hope I shall not offend any one, by taking the liberty to put my own sense upon this celebrated passage; and to enquire, why it should be deemed a precept at all. To me, I must confess, it appears to contain nothing more than a declaration of what will generally happen; and in this view, to stand upon exactly the same ground with such passages as the following. †
“He that leadeth into captivity shall go into
“captivity: “He that taketh up the sword
“shall perish by the sword.” The form of expression is precisely the same in each of these texts; why then may they not be all interpreted in the same manner, and considered, not as commands, but as denunciations? And if so, the magistrate will be no more *bound* by the text in Genesis, to punish murder with death, than he will, by the text in the Revelations, to sell every Guinea captain to our West India planters.

* Gen. ix. 6.

† Rev. xv. 10. Matt. xxvi. 52.

And,

And yet, however just and proper such a proceeding might be, I suppose no one will assert, that the magistrate is *bound* to it by either that or any other text in the scriptures; or that *that alone* would be admitted, as a *sufficient reason* for so extraordinary a measure. *

But in considering the punishment of murder by death, upon the footing of *political advantage*, which alone has any thing to do with the question, may it not justly be asked, what natural reason can be given, why the loss of one member of society should necessarily be followed by the loss of another! And, if none *can* be given, whether the present practice, on such occasions, is any thing more, than a barbarous expedient to get rid of a difficulty, than hastily *cutting* a knot, because a little dexterity is requisite to *untie* it?

It would surely better become a wise politician, to enquire, what are the springs which lead men to the commission of crimes; and so to suit his punishments to particular offences, as that they shall in their own nature tend to prevent them, and correct their evil influence; and not to inflict random punishments, merely to make the delinquent suffer.

* Let it also be observed, *by those who will quote scripture upon the occasion*, that when Cain murdered Abel, God only *set a mark* upon him, that is, rendered him infamous. 'This is a scripture precedent!'

Now

Now it will not be difficult to shew, that the principal springs of evil actions are, *pride, luxury, and idleness*, assisted by the influence of *bad examples*. To correct the ill effects of these things, we at present confine our prisoners in a state of *absolute indolence*, in the company of the *most detestable* of their species, who *encourage*, instead of *shaming* them, *with free access to the means of intemperance*, the goaler being generally a publican, and after five or six months of *this kind of discipline*, we *whip, banish, or hang* them. In other words, we *cherish*, as much as we are able, those *principles*, and *confirm*, beyond the possibility of amendment, *those habits*, which are the *foundations of all vicious conduct*; and then inflict upon them a momentary punishment, which, if they survive, they return into society prepared *by ourselves* to become its most detestable members; and if their punishment be the conclusion of their present existence, we have been *doing them an injury which we cannot repair*, by contriving for the last months of their lives such a course of conduct, as was sure to confirm their vicious principles and habits.

Is all this rational and wise? Does it manifest sound judgment, or good policy? Surely not. Right reason would suggest a very opposite proceeding. To counteract the effects of idleness and luxury, and prevent the influence of bad company, it would shew, that it was
much

much more eligible, to apply the punishments of *shame*, *hard labour*, * *coarse diet*, and *solitary confinement*; and these in different degrees, according to the different enormity of the offences committed, and in proportion as they have arisen from one or another of these causes.

Many advantages seem likely to arise from this mode of punishment. That the *certain* infliction of *hard labour* would have more influence upon the mind of the offender, than the present *bare probability* of death, may naturally be supposed, and indeed has been frequently experienced. And the duration of the punishment would make a much deeper impression upon spectators, than the *instantaneous execution* of a criminal, and would therefore tend to deter more effectually from the commission of crimes in future. In suffering this kind of punishment also, the offender is compelled, in some degree at least, to support himself by his own labour, as long as he remains under confinement; he will also form habits of temperance and industry, and thus be prepared for usefulness in the world, when the term of his punishment is elapsed. And that the reformation of the offender will be very much promoted by some portion of

* Diodorus Siculus tells us, that Sabaco, king of Egypt, changed capital punishments, with much success, into stated kinds of labour. Whose example Grotius recommends.

solitary confinement (affording him opportunities of reflection, breaking him from the society of his old companions, &c.) has been sufficiently shewn by the excellent Mr. Howard, in his *State of the Prisons in Holland*. *

But the best method, where it can be done, of amending our penal code, is to take away all occasion for its severe institutions, by preventing, as much as possible, the crimes they restrain from being committed; or in other words, by having recourse to such previous expedients, † as shall remove every prospect of advantage from their commission. Thus,* while no other precautions were used to prevent the *coining of gold*, than the making it a capital crime, the offence grew every day more frequent; but, as soon as the late regulations respecting gold coin took place, which entirely preclude every

* See particularly his story of the *shoe-maker*, who always drank the health of his friends, the masters of the Rasp-house, for teaching him sobriety and industry.

† Laws which only take effect *à posteriori*, and propose the prevention of crimes by cutting off the delinquent, will never reform; whereas prudent provisions to correct the morals, and proper punishments to counteract the principles of criminality, will have sure and lasting effects. Without such provisions, we may be making perpetual alterations, but shall in vain expect any salutary effects; we shall resemble those patients who are always taking physic, but will not alter their bad diet, and intemperate modes of living. Crim. Law, p. XIX.

prospect of advantage from this practice, the offence died away of itself; and we now scarcely ever (I believe I may say *never*) hear of a single offender in this respect.

These are the expedients which have hitherto been used in those countries, where attempts have been made to substitute other punishments in the room of capital ones, and otherwise to reform the penal institutions; and they have, I believe, been almost universally attended with success. The governments of China, Russia, * and Prussia have been foremost in these experiments, while other, perhaps more perfect, states, have not pursued this laudable measure so far as might have been expected. Even in England, this excellent work has not hitherto been entered upon with proper spirit. Our penal laws have too frequently been the work of a few, influenced by various improper passions, and not directed by that coolness which legislators ought always to possess. They have too often been made *upon the spur of the occasion*, as Lord Bacon expresses it, and when so made, their revival has been afterwards neglected; † or we should

• Grand instructions for forming a code for the Russian Empire. § 210.

† If Lord Ashburton really was engaged, as we were told, in the revival, amendment and digestion of our code of penal laws, his death is much to be lamented by every friend to humanity.

not,

not, in the eighteenth century, * have had reason to acknowledge with shame, that stealing a swan, ¹ breaking down a cherry tree, ² letting out the water of a fish pond, ³ being seen in the company of gypsies, ⁴ with upwards of a hundred and fifty other actions which a man is daily liable to commit, ⁵ are declared, by English Acts of Parliament, *crimes worthy of instant death!*

Is not this a fact at which Englishmen should blush? And ought not our legislators to undertake, without delay, the great but necessary work of reforming these sanguinary and impolitic statutes? Our country gloriously led the way in the abolition of torture; let us not be ashamed to follow the good example which others have set us in return, and still further

* Blackstone. vol. IV. p. 4.

¹ Dalt. Just. C. CLVI.

² 31st Geo. II. C. XLII.

³ 9th Geo. I. C. XXII.

⁴ 5th Eliz. C. XX.

⁵ Ruffhead's Index to Statutes.

After this, will not any one acknowledge that Judge Foster, in the preface to his Crown Law, recommends its study with singular propriety, as a matter of universal concernment? "For," says he, "no rank or elevation in life, *no uprightness of heart*, *no prudence or circumspection* of conduct, should tempt a man to conclude, that he may not, at some time or other, be deeply interested in it."

humanize our civil institutions. We shall then have performed a work for which posterity will regard us with gratitude ; and our age will then stand a chance of still acquiring the same reputation for humanity and public spirit, which it justly merits for the encouragement it affords to improvements in the arts and sciences.

To conclude ; It has been the object of this discourse to prove ;

That the *end* of all punishments is, not to torment a sensible Being, but to prevent the future commission of crimes ;

That those only can be deemed proper *subjects* of human punishments, who have been proved guilty of offences against the peace and good order of society ;

That the *political enormity* of offences, or that which fixes the proportion of their punishment, is to be estimated by the degree of detriment they occasion to the state ;

That the *nature* of all punishments should be so suited to their respective offences, as that they shall naturally tend to prevent their future commission, by correcting the principles which gave rise to them :

That the magistrate has no right to inflict punishments *unnecessarily severe* ;

That he ought to be very sparing (if he have recourse to them at all) in the use of *capital punishments* ;

And

And that in every instance he ought to appoint only such sanctions to his laws, as shall be *adequate, and no more than adequate*, to prevent the *crimes which* are the objects of them.

If, in the course of this slight Essay, any thing has been offered in the least degree worthy the attention of this respectable Society, and more especially, if it should be the means of furnishing agreeable and useful topics of debate, its end will be answered, and its author satisfied.

Mem. The rule, "That the measure of punishment shall be such as may be adequate to the prevention of the offence," must only be extended to such offences as it is in the magistrate's power to prevent without occasioning a greater evil than will arise from its permission. Judge Blackstone happily observes, "The damage done to our *public roads* by loaded waggons is universally acknowledged, and many laws have been made to prevent it, none of which have proved effectual." *But it does not therefore follow that it would be just in the legislature to inflict death upon every obstinate carrier who defeats or eludes the provisions of former statutes.* Vol. IV. p. 10.

On the PURSUITS of EXPERIMENTAL PHILOSOPHY.
By THOMAS PERCIVAL, M. D. F. R. S. and
S. A. &c. Read May 14, 1784.

Homo, naturæ minister et interpret, tantum facit et intelligit, quantum de naturæ ordine, re vel mente, observaverit; nec amplius scit, aut potest. BACON, NOV. ORGAN. APH. I.

THE very learned and ingenious author of *Hermes* * has stigmatized the pursuits of modern philosophy, by treating them as mere *experimental amusements*; and charging those who are engaged in such pursuits, with deeming nothing *demonstration*, that is not made *ocular*. Thus, instead of ascending from *sense* to *intellect*, the natural progress of all true learning, he observes, that the philosopher hurries into the midst of *sense*, where he wanders at random, lost in a labyrinth of *infinite particulars*. It would be easy to retaliate on this celebrated writer, by pointing out the futility of the syllogistic mode of philosophizing, instituted by his favourite Aristotle. I might also oppose to his authority, that of Lord Verulam, the brightest luminary of

* See a Philosophical Enquiry concerning universal Grammar, by James Harris, Esq. p. 361.

science, who objects, in the strongest terms, against that reverence for speculations, purely intellectual, “ by means whereof,” as he expresses himself, “ men have withdrawn too much “ from the contemplations of nature, and the “ observations of experience, and have tumbled “ up and down in their own reason and conceits. “ Upon these intellectualists, who are notwithstanding commonly taken for the most sublime and divine philosophers, Heraclitus gave “ a just censure, saying, *men sought truth in their “ own little worlds, and not in the great and common “ world.*” *

But, without depreciating metaphysics, a science which I have always studied with delight, and which invigorates the faculties of the mind, and gives precision and accuracy to our rational investigations by instructing us in the nicer discriminations of truth and falsehood, no doubt can be entertained of the high importance and dignity of natural knowledge. To this we owe the necessities, the conveniences, and all the gratifications of our being; † and in the pursuit of it the understanding is exercised and improved, and our

* Bacon on the Advancement of Learning, book I. p. 20. 4to.

† *Scientia et potentia humana in idem coincidunt.* BACON, Nov. Org. Aph. III.

moral affections are elevated to superior degrees of piety, towards the great Author of all that is fair and good in the creation. Nor is modern philosophy liable to the charges, which have been thus contumeliously brought against it. For, I trust, it has been conducted, on the principles of genuine *logic*, by all its more distinguished professors, who have been sedulously careful first to establish sound premises, and then to deduce just conclusions.

The immortal Newton, from an appearance, which we daily observe, the fall of bodies to the ground, ascended by patient investigation, and by a regular gradation of evidence, to the great law of gravity. And having ascertained this general principle, he extended it over the universe, explaining by it not only the phænomena of our globe, but the revolutions of the whole planetary system. By the successive adoption of the same *analytic* and *synthetic* mode of reasoning, he demonstrated his beautiful theory of light and colours. Numberless other subsequent discoveries have been conducted on the same scientific plan, as might be evinced by references to the writings of our own and foreign philosophers.

Even the chemists have long since deserted their jargon and mysterious conceits; and they now carry on their researches in a perspicuous and rational manner. That unknown principle phlogiston, to which they referred so many operations

tions of nature, explaining, as the logicians express it, *ignotum per ignotius*, has been lately proved to be no creature of the imagination; and may be exhibited to the senses, under the form of inflammable air. Fire, subtle as it is in its activity, and universal in its energy, has been traced through all its modifications, measured by different standards, and reduced to known, precise, and permanent laws. It is therefore no just complaint, that intelligent principles are neglected, and that empiricism in physics is honoured with exclusive encouragement. Yet, in the prevailing rage for experiments, it cannot be unseasonable to caution the young adventurer, not to deem the microscope, the retort, or the air-pump unerring guides to truth; but to prosecute his researches into nature with a modest conviction of the fallacy of his senses, and the limited powers of his understanding. "You will wonder," says Mr. Boyle, in the preface to his essays, "that I should use so often "*perhaps; it seems; 'tis not improbable;* words, "which argue a diffidence of the truth of the "opinions I incline to. But I have hitherto "not unfrequently found, that what pleased me "for a while, was soon after disgraced by some "further or new experiment."

Mr. Bewley, an eminent chemist, not long since, informed me, that he concluded the presence of the vitriolic acid to be unnecessary to
produce

produce the spontaneous accension of Homberg's pyrophorus, and delivered this opinion to the public, on the evidence of at least fifty different trials.* Yet, with materials taken from the same bottle, the experiment afterwards failed nearly as often, though the minutest circumstances in the process were as much alike, as attention could render them. Contrarieties, equally humiliating, have often occurred in my own philosophical pursuits. But the most instructive lesson of modesty and reserve, which I recollect in the course of my experience, is the one I shall now briefly recite.

The favourable influence of fixed air on vegetation I believed to have been ascertained by more than a hundred experiments; which I made in the year 1775. Many of these experiments were repeated afterwards by Mr. Henry, Mr. Bew, and others. But Dr. Priestley, whose accuracy and fidelity are not less distinguished than his learning and ingenuity, has since drawn conclusions from the prosecution of this subject, which militate totally with mine. I resumed the enquiry, and engaged several of my friends in it. The result of all our trials was uniformly the same as before, viz. that fixed air, in a due proportion, is so favourable to vegetable growth,

* See Priestley on Air, vol. III. Appendix, p. 395.

that

that it may justly be deemed a pabulum of plants. Dr. Priestley's subsequent experiments, however, were still contradictory to mine: And in one of his very friendly letters to me, he thus expresses himself. " In all these cases, " you will say, I choak the plants with too " great a quantity of *wholesome* nourishment: " And to all yours I say, you do not give them " enough of the *noxious matter* to kill them. " Thus the amicable controversy must rest between us; and like all other combatants, we " shall both sing TE DEUM." But I felt little disposition to exultation on such an occasion, and dropt the subject, conscious that though nature is always the same, we often view her under fallacious appearances. Time, however, and the researches of foreign philosophers have thrown new lights on this disputed point. And I am informed, by a letter from our common friend, Mr. Vaughan, that Dr. Priestley now admits the salubrity of fixed air to vegetable life. I shall copy the paragraph, which contains the account. " Dr. Priestley tells me " of a very valuable book, written by a person " at Geneva, on vegetation; particularly as to " the influence of light, which he maintains to " be a phlogisticating process, acting on the " resinous parts of plants only. He also " affirms, to the satisfaction of Dr. Priestley, " that not only phlogiston is the grand pabulum " of

“ of plants, but that its predominant form
 “ of reception is that of fixed air; which, in a
 “ proper degree and place of application, he
 “ shews to be salutary to all plants whatever.”

Differences in the results of our enquiries, or in those of others, whilst they incite attention, and guard us against confidence and presumption, should neither diminish the veneration due to philosophy, nor repress our temperate ardour in the pursuit of truth. We should recollect that though the operations of nature are simple, uniform, and regular, they are only discovered to be such, when fully unfolded to our understandings. And that, when we endeavour to trace her laws, by artificial arrangements, combinations, or decompositions, which is all that *experiment* can accomplish, * success may be sometimes frustrated by circumstances so minute, as to elude the most sagacious observation. From the history of electricity it appears, that the gentlemen, first engaged in the culture of that science, ascribed opposite effects to the use of boiling water in the Leyden phial. M. Jalabert, of Geneva, and others invariably found, that the electric powers of the bottle were increased by the water; whereas Messrs. Kinnerley, Nollet, and Watson, experienced the reverse, in all their trials. It has

* Ad opera nil aliud potest Homo, quam ut corpora naturalia admoveat, et amoveat; reliqua natura ipsa intus transigit. Bacon. Nov. Organ.

since been shewn that the jarring decisions of those learned men, were owing to the difference in the action of boiling water on the several kinds of glass employed. Contradictory opinions are now held, by two very celebrated chemists, concerning the nature of steel; one asserting that its phlogiston is augmented, the other that it is diminished, in the process by which it is made. Both appeal to experiment in support of their opinions; and as the point in dispute is of importance to the arts, it merits a more compleat and satisfactory investigation.

To these examples I shall add another, in which I have myself been particularly interested. The Rev. Dr. Hales, whose experimental inquiries were generally directed to the good of his fellow-creatures, discovered a lithontriptic power, in certain fermenting mixtures. But he acknowledges the impracticability of injecting such mixtures into the bladder, with sufficient frequency, to dissolve the stone; and recites his experiments chiefly with a view to engage others in the same laudable and important pursuit. The subject however sunk into oblivion, and no further attempts of this kind were made, till the notice of the public was again excited towards the properties and uses of factitious air, by the writings of various learned and ingenious men. At this time (1774) Dr. Saunders, a physician in London, eminent for his knowledge of chemistry,

mistry, renewed the experiments which Dr. Hales had begun, and found that the solvent power, ascribed to the fermenting mixtures, resided only in the fixed air: Hearing some very imperfect accounts of this discovery, curiosity and humanity engaged me in the pursuit of it. I recollected that Dr. Black and Mr. Cavendish had proved the solubility of various earthly bodies in water, either by abstracting from, or superadding to the fixed air, which they contain. And as the human calculus is dissolved in the former way, by lime water and the caustic alkali, it appeared to me highly probable; that the effect would be produced, in the same substance, by the latter mode of operation. Analogy seemed favourable to the hypothesis, and a series of experiments, which I made with great care, in the fullest manner confirmed it. Two years afterwards, Dr. Falconer engaged in the same enquiry; and the results of his trials exactly coincide with those which I have related. This united evidence has been also strengthened by the subsequent testimony of Dr. Priestley and Dr. Hulme. Yet decisive as it appears to be, a friend of mine, who is a very able and accurate experimenter, assures me, that the *calculi*, which he has tried, uniformly resist the action of mephitic water. And he further adds, that not one of them has been found to contain a single grain of absorbent earth; but that all of them proved
inflam-

inflammable, like gall-stones. Dr. Heberden has, also, favoured me with similar information, respecting their analysis. On the other hand, I have fully shewn, that these substances vary in their structure and composition; that calcination converts some into quicklime; that others are consumed entirely in the fire; and that a third sort yield, after burning, an insipid residuum, incapable of giving any impregnation to water.* What then are we to infer from premises, apparently so inconsistent? Let us deduce from them these salutary lessons; that dogmatism is unbecoming a philosopher; that fallacy may attend our clearest views; and that unperceived diversities, in the subjects of our investigation, may render truth compatible with contrariety of evidence.

An eagerness to establish systems, and a fastidious disdain of perplexity, contradiction, or disappointment, are dispositions highly unfavourable to physical investigation. Lord Bacon has well observed, "that one, who begins with certain-
"ties, shall end in doubts; but if he will be
"content to begin with doubts, he shall end in
"certainties."† The progress of science is usually slow and gradual; and in all ordinary cases, the *pace is not to the swift*, but to the steady, the patient, and the persevering. A man of lively

* Philosoph. Medic. and Experim. Essays, vol. III. p. 161.

† Advancement of Learning. Book I. p. 20.

parts, and fertile imagination, generally engages in philosophical researches, with too much impetuosity; and if he be fortunate in the attainment of a few leading facts, he supplies all remaining deficiencies by conjecture and hypothesis. But should his career be obstructed by contradictory phænomena, he quits the study of nature with disgust; and concludes that all is uncertainty, because he has had the mortification to find himself mistaken. A scepticism like this, founded in pride and indolence, is equally subversive both of speculation and of action. We can apply to no branch of human learning, which is secure from illusion, or exempt from controversy; nor engage in any plan of life with undeviating judgment, and uninterrupted success. So true is the sentiment of the Roman poet.

Nunquam quisquam ita bene subducta ratione ad vitam fuit,
 Quin res, ætas, usus, semper aliquid apponet novi;
 Aliquid admoneat: ut illa, quæ te scire credas, nescias,
 Et quæ tibi putaris prima in experiundo repudies.

TERENT.

But as disappointments in life often furnish the best lessons of wisdom, so those in philosophy may, frequently, be applied to the promotion of science. In experimental pursuits, which are not undertaken at random, but with consistent and rational views, we necessarily form a pre-conception of the induction to be established. If the trials succeed, in which we are engaged,

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our end is obtained, and; for the most part, we rest satisfied. But if the proofs fail, some unexpected phænomena often occur, which awaken our attention, suggest new analogies, and excite us, perhaps, to the investigation of other propositions of more importance than the antecedent ones. The very interesting and comprehensive discoveries of Dr. Black, concerning the nature of calcareous earths, and alkaline salts, in their different states of mildness and causticity, originated from an incident of this kind.* And many similar examples might be adduced from the records of philosophy. But whether such be the fortunate event or not, a negative truth may be of as much value as a positive one; and consequently, success or disappointment may prove equally useful in experimental researches.†

To deduce the general characters of a body from one single property of it, individually considered, seems contrary to the rules of philosophizing. And the young experimenter should be cautious both of admitting, and of forming such analogies. Yet they are sometimes so strong as to force conviction even against the evidence of sense, and of general opinion. The diamond

* See *Essays Physical and Literary*.

† See the *Author's Essays Medical and Experimental*, vol. I. p. 106. edit. third.

was held by chemists, in the time of Sir Isaac Newton, to be apyrous, and could not be suspected, from any of its known qualities, to be of an inflammable nature. Yet this vigilant philosopher did not hesitate to consider it as an *unctuous coagulum*, solely from its possessing a very high degree of refractive power on the rays of light. For this power he found to depend chiefly, if not wholly, on the sulphureous parts of which bodies are composed. Late experiments have confirmed this opinion; and fully proved that diamonds consist almost entirely of pure phlogiston, since they are capable of being volatilized by heat in close vessels, of pervading the most solid porcelain crucibles, and of being converted into actual flame.

The accuracy of this inference is a striking proof of the importance of judicious and comprehensive analogies; and of the advantages resulting from the mode of reasoning by induction. For, to use the words of Sir Isaac Newton, “ though the arguing from experiments and “ observations, by induction, is no *demonstration* “ of general conclusions, yet it is the best way “ of arguing, which the nature of things admits “ of; and may be looked upon as so much the “ stronger, by how much the induction is more “ general.” This improved species of logic was first recommended and introduced into physics, by Lord Verulam; who, at a very early period

period of life, saw the futility of Aristotle's syllogistic system, which, proceeding on the superficial enumeration of a few particulars, rises at once to the establishment of universal propositions. *Dux viæ sunt, atque esse possunt, ad inquirendam et inveniendam veritatem. Altera a sensu et particularibus advolat ad axiomata maxime generalia, atque ex iis principiis, eorumque immota veritate judicat et invenit axiomata media; atque hæc via in usu est. Altera à sensu et particularibus excitat axiomata, ascendendo continenter et gradatim, ut ultimo loco perveniatur ad maximè generalia; quæ via vera est, sed intentata.**

It is obvious that the force of this inductive method of reasoning must depend on the advancement, which has been made, in the different branches of physics. Indeed, it presupposes a store of particular facts, gradually accumulated, but sufficiently ample, and fit for reduction into their proper classes. Time and observation will be continually diminishing the number, and consequently enlarging the boundaries of these classes, by discovering other relations between them, and pointing out the connection of phenomena, deemed, at first, distinct and independent. But it must be remembered that every accession to knowledge renews the doubts and difficulties, that result from ignorance; be-

* Bacon. Nov. Organ. Lib. I. Aphor. 19.

cause it presents fresh objects to our investigation, and further desiderata to our wishes. It is this endless progression of science, which, by gratifying curiosity with perpetual novelty, and animating ambition with prospects of higher and higher attainments, sometimes gives the attachment to it an ascendancy over every other principle, so as to render it the *ruling passion* of the mind. And as this passion does not, like the love of virtue, temper its particular exertions, by preserving a proper subordination in the powers, which it calls forth into action, the wildest extravagances of emotion and of conduct, have been indulged by those, who submit to its uncontrouled dominion. A great philosopher has rushed naked, from the bath, into the streets of a populous city, frantic with joy, on the solution of an interesting problem. But as I have expatiated in another Essay, * on the folly of such extravagant ardour in the pursuits of knowledge, I shall close these reflections with the following lines from Milton.

- - - Apt the mind, or fancy, is to rove
 Unchecked, and of her roving is no end;
 'Till warn'd, or by experience taught she learn,
 That not to know at large of things remote
 From use, obscure and subtle, but to know

* On Inconsistency of Expectation in Literary Pursuits;
 Moral and Literary Dissertations, page 183.

That which before us lies, in daily life,
Is the prime wisdom ; what is more is fume,
Or emptiness, or fond impertinence,
And renders us in things, that most concern,
Unpractis'd, unprepar'd, and still to seek.

Par. Lost. Book VIII.

OBSERVATIONS *on the* INFLUENCE *of* FIXED AIR
on VEGETATION ; *and on the* PROBABLE CAUSE
of the DIFFERENCE *in the* RESULTS *of* VARIOUS
EXPERIMENTS *made on that* SUBJECT ; *in a*
LETTER *from* Mr. THOMAS HENRY, F. R. S.
to THOMAS PERCIVAL, M. D. F. R. S. *and*
S. A. *Read May 14, 1784.*

DEAR SIR,

IT is now many years since, from some experiments which you had made on the effects of fixed air, applied to the leaves and roots of plants, you, as appeared to me at that time, justly concluded that fixed air affords a pabulum for plants, which is equal to the support of their life and vigour, for a considerable time. Some of these experiments were seemingly contradictory to the results of those related by Dr. Priestley in his first volume. The doctor therefore requested that you or I would repeat them in vessels con-

taining *pure* fixed air. For the doctor had found that plants, confined in *pure* fixed air, perished sooner than in common air.

I all along understood your meaning to be, not that fixed air, in a pure state, and quite stagnant, was nutritive to plants; but, that gradually applied, and in a continued stream, while the plant, at the same time is not confined from the common air, (in a manner analogous to what may probably take place in nature) plants do receive such a portion of nutriment, from the fixed air, as is sufficient for their temporary support, even when removed from every other means of receiving their food. This at least was the idea which I always entertained; and the conclusion to be drawn from this theory is, that, probably, fixed air constitutes a part of the food of plants, when growing in their proper element; such air being discharged by the different manures, which are mixed with their native soil; and this theory, if just, may lead to considerable improvements in agriculture. In the third volume of Experiments and Observations on different Kinds of Air, Dr. Priestley at the same time that he acknowledges that "he could conceive nothing more fair and decisive than your experiments," yet declares himself convinced that there must have been some fallacy in them, and he seems to think that he had detected it in two instances. The first supposed cause of error

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was that your standard plants, had not been placed in similar vessels to those which had been exposed to the fixed air; and the other, that, as your experiments were made in Nooth's machine, and as you had not ascertained the proportion of fixed air which was contained in your vessel, it was, probably, much smaller than you had imagined. *

To shew the probability of this opinion, he has related a number of experiments, by which he found that fixed air, in all proportions, from a state of purity, to that of a mixture of $\frac{1}{8}$ fixed air to $\frac{7}{8}$ common air, was injurious to vegetation, and destructive to the colour of rose leaves. Yet, with his usual candour, he published, in the Appendix to that volume, an account of several experiments, which I had transmitted to him, in the latter end of the year 1776. †

By these it appeared that a strawberry plant had not only been preserved alive, exposed in the middle of Nooth's machine, to copious streams of fixed air, from the 23d of April to the 14th of May, but that the blossoms, which were only budded when put into the machine had actually expanded. A strong proof that the plant had continued to vegetate. It was then alive, but

* Dr. Priestley was mistaken in this supposition, as will appear in the sequel.

† These had been made previous to Dr. Priestley's request,

rather drooping, and having been crushed in taking out of the machine, was thrown away.

Two sprigs of mint, with some loose earth adhering to their roots, were also kept in similar vessels, from the 1st of September to the 12th of the same month. To the one a continued current of fixed air was supplied. The roots of both were cut off on the 7th. The sprig in common air exhibited symptoms of decay on the 12th day, but that in the stream of fixed air continued fresh above a week, after that in the common air was decayed nearly to the top. The experiment was then discontinued, and the remaining plant soon withered.

The next year I made the following experiments, which farther confirm the truth of the preceding ones which had been made both by you and myself. In these, as also in those just related, the first cause of error was avoided, and the proportion of fixed air was, in some of them, ascertained.

1777, April 11th, The weather being very cold and vegetation backward—The middle part of Nooth's machine was entirely filled with fixed air, by first filling it with water, inverting it in the same fluid, stopping up the capillary tubes, and then driving out the water, from the vessel, by fixed air from an effervescing mixture. The middle, was then immediately placed on the lower, part of the machine, containing an effervescing mixture also, which had been working
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for several minutes, and a crimson polyanthos was introduced into the middle part, and suspended by a string. In passing through the mouth of the vessel, the petals were necessarily compressed, and one or two received some damage. The effervescence was kept up briskly.

On the same day, and into the same vessel, a young sprig of mint, with its root, was introduced, and a similar sprig was placed in a large glass decanter as a standard. The edges of the former were much nipped by some severe winds which had prevailed, and had a yellowish hue.

The polyanthos did not begin to droop till the 15th. On the 16th it was taken out shrivelled, but the colour not changed.

The mint examined on the 12th was more fresh than when first put into the vessel with fixed air. The next day two young shoots appeared more vigorous. On the 15th its appearance was more vivid than that in common air, but the next day it was apparently dead, and was taken out in a flaccid state.*

April 26th, A polyanthos plant, with its root and flowers, was purchased in the market, with

* The machine having no valve, and having been violently shaken, I suspected that some of the vitriolic acid had been forced up the tubes; for the moisture, in the inside of the vessel, was more acid than it would have been from the fixed air only.

several others, and placed in Nooth's machine, where it was continued till the 10th of May. The effervescence was frequently renewed for the first four days, then twice, and afterwards once a day, but the discharge of air was continually going on. It continued ten days without any signs of decay; and, when taken out of the machine on the 14th day, though some of the older flowers were fading, the others were as fresh and blooming as when first put into the vessel. More so than those of the other plants which had been purchased the same day, and had been planted in the garden. The body of the plant was green, succulent and undecayed. The air extinguished flame, and, on trial, was $\frac{1}{2}$ fixed air; and during several days, the proportion of fixed air must have been larger.

But *confined* in vessels of fixed air; or even in Nooth's machine, with the upper part and grooved stopper put on, plants died sooner than in common air. The air measured was $\frac{2}{3}$ fixed air.

I am informed that an ingenious philosopher of Geneva has made some experiments, in which he has proved, not only, that phlogiston is the food of plants, but also, to the satisfaction of Dr. Priestley, that it is in the form of fixed air, in proper proportion and place, that this pabulum is administered. The latter is the whole that we contended for; and, which, we thought, we had
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satisfactorily proved, eight years since. On this occasion, therefore, I thought it not improper to recur to my journal of experiments, and to take this method of laying an account of them before the Literary and Philosophical Society; in order to ascertain your claim to the discovery in question.

In regard to the animal body, it would surely be wrong to say that nothing was nutritious or salutary to it, but what it could bear to receive unmixed or undiluted. Why then may we not suppose that though fixed air, when pure, may be fatal to plants confined in it; and excluded from free communication with the common air, yet when applied in proper dose, and to plants enjoying a free intercourse with the atmosphere, it may have a contrary effect, and serve to nourish and support them?

But in Dr. Priestley's experiments, this *free intercourse* does not appear to have been allowed; and herein, I apprehend, consisted the cause of the difference in our results.

At that time, the constitution of fixed air was not understood. It is now, *generally*, allowed to be formed by a combination of phlogiston with the pure part of atmospheric air. The first of these ingredients has been proved, by the experiments of Dr. Priestley and others, to be favourable to vegetation, while plants droop and decay when exposed to the action of the latter. It
should

should further appear, from Dr. Ingenhouz's train of experiments, that plants have the power of separating phlogiston from common air, applying it to their nurture, and throwing out the pure or dephlogisticated residuum, as excrementitious. Now allowing, what appears highly probable, that they have a similar power of decomposing *fixed air*, and of applying and rejecting its constituent parts, our method of conducting the experiments was *not* injurious to the process; whereas, when confined in close vessels, as by Dr. Priestley, the plants would be suffocated, in a manner reversed to what would happen to an animal. For as in that case, from a want of communication with the atmosphere, as necessary to carry off the phlogiston thrown out from the lungs, (according to the beautiful theory of respiration, advanced and so well supported by Dr. Priestley) the animal must perish; so, in the other instance the plant would die, if cut off from the air of the atmosphere, in such manner, that the pure air excreted by its vessels could not be conveyed from it. For, in these circumstances, this fluid, so salutary to animal, but destructive to vegetable, life, must be accumulated in the body of the plant, and, its functions being thus impeded, death is the necessary consequence.

This reasoning seems to be confirmed by some of the facts which you have communicated to me, from your Journal. For it appears, from
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several of your experiments, that during seven hours of the day, viz. from 10, A. M. to 5, P. M. the plants, you employed, were exposed to varying proportions of fixed air, seldom exceeding $\frac{1}{2}$ the proportion of air, contained in the vessel, and never less than $\frac{1}{4}$. But, from 5 o'clock in the evening till 10, the succeeding day, the quantity of fixed air seems to have varied, from $\frac{1}{2}$ to $\frac{1}{17}$ of the whole air. Now a plant exposed to such diversified proportions of air, passing too in a stream through the vessel, must be in a favourable state, both for exhalation, and consequently for the process of inhalation also.

I am, dear SIR,

With the most perfect regard,

Your faithful, affectionate Friend,

THOMAS HENRY.

MANCHESTER, May 12, 1784.

OBSERVATIONS *on a* THIGH BONE *of* UNCOMMON LENGTH. By C. WHITE, Esq. F. R. S. &c.
Read November 10, 1784.

I N different parts of Siberia, as well in the mountains as the valleys; likewise in Russia, Germany, Peru, the Brazils, and North America, on the banks of the Ohio near the river Mimme, seven hundred miles from the sea-coast, and five or six feet beneath the surface of the earth, there have frequently been found, at various times, fossil tusks and bones of a very large size, somewhat resembling those of the elephant. In temperate climates, the tusks are softened, and converted into fossil ivory; but in countries frequently frozen they are generally found very fresh. Many of them may be seen in the Imperial Cabinet at Petersburg, in the British, Dr. Hunter's, and Sir Ashton Lever's Museums, and in that of the Royal Society. According to tradition, these were reported to be the tusks and bones of the *Mammouth*, an animal, which, if ever it existed, is not now, that we know, any longer an inhabitant of any part of this globe. A description of the Mammouth
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is given by Muller.* This animal, he says, is four or five yards high, and about thirty feet long. His colour is greyish. His head is very long, and his front very broad. On each side, precisely under the eyes, there are two horns, which he can move and cross at pleasure. In walking he has the power of extending and contracting his body to a great degree. Mbrandes Ides gives a similar account; but he is candid enough to acknowledge, that he never knew any person who had seen the Mammouth alive. Mr. Pennant, however, thinks it “ more than
 “ probable, that it still exists in some of those
 “ remote parts of the vast new Continent, impenetrated yet by Europeans. Providence,” he adds, “ maintains and continues every created
 “ species; and we have as much assurance, that
 “ no race of animals will any more cease while
 “ the earth remaineth, than *seed time and harvest,*
 “ *cold and heat, summer and winter, day and night.*”

Several eminent naturalists of late years, as Sir Hans Sloane, † Gmelin, ‡ Daubenton, and Buffon, are of opinion that these prodigious bones and tusks are really the bones and tusks

* Moeurs & Usages des Ostiaques dans le *Recueil des Voyages au Nord*.

† Histoire de l'Acad. des Sciences Ann. 1717. p. 1.

‡ Relation d'un Voyage a Kamtschatka par M. Gmelin en 1735.—*A Peterburgh-en langue Russe.*

of elephants; and many modern philosophers have held the Mammoth to be as fabulous as the Centaur.

The great difference in size they endeavour to account for, as arising from difference in age, sex, and climate; and the cause of their being found in those northern parts of the world, where elephants are no longer natives, nor can even long exist, they presume to have arisen from hence; that, in the great revolutions which have happened in the earth, the elephants, to avoid destruction, have left their native country, and dispersed themselves wherever they could find safety. Their lot has been different. Some in a longer, and others in a shorter time after their death, have been transported to great distances by some vast inundations. Those, on the contrary, which survived, and wandered far to the north, must necessarily have fallen victims to the rigours of the climate. Others, without reaching to so great a distance, might be drowned, or perish with fatigue.

In the year 1767, Dr. Hunter, with the assistance of his brother, Mr. J. Hunter, had an opportunity of investigating more particularly this part of natural history, and has evidently proved, that these fossil bones and tusks are not only larger than the generality of elephants, but that the tusks are more twisted, or have more of the spiral curve than elephants' teeth, and that
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the thigh and jaw bones differ in several respects from those of the elephant; but what put the matter beyond all dispute, was the shape of the grinders, which clearly appeared to be those of a carnivorous animal, or at least of an animal of the mixed kind, being furnished with a double row of high and conic processes, as if intended to masticate, not to grind the food, and the enamel making a crust on the *outside* only of the teeth, as in a human grinder. They totally differ from those of the elephant, which is well known not to be of the carnivorous, but graminivorous kind, both by the form of its grinders, and by its never tasting animal food. A few years ago, I had in my possession an elephant's grinder, which Sir Ashton Lever did me the honour to place in his elegant Museum. This is flat, and ribbed transversely on its surface.

Some have supposed these fossil bones to belong to the hippopotamus, or river horse; but there are many reasons against this supposition, as the hippopotamus is even much smaller than the elephant, and has such remarkably short legs, that his belly reaches within three or four inches of the ground.

The late Dr. Hunter, in a paper on this subject, read before the Royal Society the 15th of February 1768, and published in the transactions of that year, gives a particular account of several tusks and grinders in the tower, which came from the Ohio, and others which Dr.

Franklin had received from the same place. These tusks and grinders, Dr. Hunter was fully convinced, were not, as was supposed, of the American elephant, but belonged to an animal of another species, a *pseud-elephant*, or *animal incognitum* as he calls it, which naturalists are now unacquainted with; and from the form of the knobs on the body of the grinders, and the disposition of the enamel on them, which makes a crust on the outside only of the tooth, as in a human grinder, his brother Mr. J. Hunter was convinced that the animal was either carnivorous, or of a mixed kind. Those who wish to have a further account of this subject, I must beg leave to refer to the doctor's ingenious paper.

The thigh bone, which I have now the honour to shew to this Society, was given to me by Mr. Hardman, of Ardwick, who purchased it at Liverpool. It was found in a room in that town, from whence some people, who kept wild beasts, had suddenly decamped in the night, and, it is supposed, left this bone behind them. This is all I could learn of its history. It is evidently the left thigh bone of some amazingly large animal. The *length* of it, is three feet ten inches and six lines; the *breadth*, in the narrowest part, four inches and seven lines. Its *thickness*, two inches and nine lines. Its *smallest circumference*, one foot and one inch; and its *weight*, forty pounds eight ounces.

On comparing this bone with the femurs
of

of Canada and Siberia, and with that of the common elephant, seven feet and a half high, described by Mr. Daubenton, in the Memoirs of the Royal Academy of Sciences of Paris, for the year 1762, it appears to bear the greatest resemblance to that of Siberia. It is longer than any of them by several inches, and is, perhaps, the longest thigh bone of any animal, of which an account has been given by any author we are acquainted with. It is neither so heavy, nor so thick, as the one from Canada, but its weight is greater than that from Siberia, and much exceeds that of the common elephant.* Dr. Hunter, in the paper before referred to, seems to have brought pretty positive proof, that these two femurs (that from Canada, and that from Siberia) are not the femurs of the elephant; and as this thigh bone before us has so great a similitude to these two, particularly to that from Siberia, there is every reason to be of the same opinion with regard to it. Whether the animal described by Muller, under the name Mammouth, has ever existed, or whether, as Mr. Pennant seems to suppose, it still exists in any parts of the world, yet unexplored, may long remain undetermined.

* Since this paper was read before the Society, the Rev. James Douglas has sent me an account of a thigh bone of this animal, in the Borough, much larger than any of these. It weighs upwards of eighty pounds, and is nearly four feet in length.

But from the shape and size of the femurs, and of the temporal, and jaw bone, there is little room to doubt their having belonged to an animal, with which we are now entirely unacquainted, and of which there are no further traces remaining. It appears to have been larger than the generality, at least, of elephants, or than any other quadruped we know; and, from the shape and nature of the grinders, it must evidently have been a carnivorous animal.

I have here subjoined a comparative view of the femurs of Canada, Siberia, and that of the common elephant, with my own; the account of the former is extracted from Mr. Daubenton's before-mentioned. The circumference, breadth, and thickness, are taken at the smallest part of the bones. The length is measured from the upper part of the head, to the lowest extremity of the inner condyle.

FEMUR of Canada.			Of Siberia.			Of Versailles.			Mr. White's				
Feet. Inch. Lines.			Ft. In. Lines.			Ft. In. Lines.			Ft. In. Lines.				
Length	3	4	9	3	4	0	2	10	3	3	10	6	
				without Epiph.									
				3	5	0							
				with Epiph.									
Breadth	0	6	8	0	5	8	0	3	2	0	4	7	
Thickness	0	3	9	0	3	$\frac{1}{2}$	0	2	4	$\frac{1}{2}$	0	2	9
Circum.	1	4	9	1	3	1	0	9	1	1	1	0	
Weight	59 pound.			38 pound 6 $\frac{1}{2}$ oz.			10 pound 12 oz.			40 pound 8 oz.			

I have also made a drawing of the bone in my possession, and reduced it to the same scale with
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the other three; more fully to shew the proportionable size of them; and of the jaw bone and grinders of the elephant, and animal *incognitum*, or *pseud-elephant* taken from Dr. Hunter's plate of them.

METEOROLOGICAL IMAGINATIONS *and* CONJECTURES. By BENJAMIN FRANKLIN, LL.D. F. R. S. *and* Acad. Reg. Scient. Paris. Soc. &c. Communicated by Dr. PERCIVAL. Read December 22, 1784.

THERE seems to be a region higher in the air over all countries, where it is always winter, where frost exists continually, since, in the midst of summer on the surface of the earth, ice falls often from above in the form of hail.

Hailstones, of the great weight we sometimes find them, did not probably acquire their magnitude before they began to descend. The air, being eight hundred times rarer than water, is unable to support it but in the shape of vapour, a state in which its particles are separated. As soon as they are condensed by the cold of the upper region, so as to form a drop, that drop begins to fall. If it freezes into a grain of

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ice,

ice, that ice descends. In descending, both the drop of water, and the grain of ice, are augmented by particles of the vapour they pass through in falling, and which they condense by their coldness, and attach to themselves.

It is possible that, in summer, much of what is rain, when it arrives at the surface of the earth, might have been snow, when it began its descent; but being thawed, in passing through the warm air near the surface, it is changed from snow into rain.

How immensely cold must be the original particle of hail, which forms the center of the future hailstone, since it is capable of communicating sufficient cold, if I may so speak, to freeze all the mass of vapour condensed round it, and form a lump of perhaps six or eight ounces in weight!

When, in summer time, the sun is high, and continues long every day above the horizon, his rays strike the earth more directly, and with longer continuance, than in the winter; hence, the surface is more heated, and to a greater depth, by the effect of those rays.

When rain falls on the heated earth, and soaks down into it, it carries down with it a great part of the heat, which by that means descends still deeper.

The mass of earth, to the depth perhaps of thirty feet, being thus heated to a certain degree,
continues

continues to retain its heat for some time. Thus the first snows that fall in the beginning of winter, seldom lie long on the surface, but are soon melted, and soon absorbed. After which, the winds that blow over the country on which the snows had fallen, are not rendered so cold as they would have been by those snows, if they had remained. And thus the approach of the severity of winter is retarded; and the extreme degree of its cold is not always at the time we might expect it, viz. when the sun is at its greatest distance, and the day shortest, but some time after that period, according to the English proverb, which says, "as the day lengthens, the cold strengthens;" the causes of refrigeration continuing to operate, while the sun returns too slowly, and his force continues too weak to counteract them.

During several of the summer months of the year 1783, when the effect of the sun's rays to heat the earth in these northern regions should have been greatest, there existed a constant fog over all Europe, and great part of North America. This fog was of a permanent nature; it was dry, and the rays of the sun seemed to have little effect towards dissipating it, as they easily do a moist fog, arising from water. They were indeed rendered so faint in passing through it, that when collected in the focus of a burning glass, they would scarce kindle brown paper.

Of course, their summer effect in heating the earth was exceedingly diminished.

Hence the surface was early frozen.

Hence the first snows remained on it unmelted, and received continual additions.

Hence the air was more chilled, and the winds more severely cold.

Hence perhaps the winter of 1783-4, was more severe, than any that had happened for many years.

The cause of this universal fog is not yet ascertained. Whether it was adventitious to this earth, and merely a smoke, proceeding from the consumption by fire of some of those great burning balls or globes which we happen to meet with in our rapid course round the sun, and which are sometimes seen to kindle and be destroyed in passing our atmosphere, and whose smoke might be attracted and retained by our earth; or whether it was the vast quantity of smoke, long continuing to issue during the summer from *Hecla* in Iceland, and that other volcano which arose out of the sea near that island, which smoke might be spread by various winds, over the northern part of the world, is yet uncertain.

It seems however worth the enquiry, whether other hard winters, recorded in history, were preceded by similar permanent and widely extended summer fogs. Because, if found to be
fo,

so, men might from such fogs conjecture the probability of a succeeding hard winter, and of the damage to be expected by the breaking up of frozen rivers in the spring; and take such measures as are possible and practicable, to secure themselves and effects from the mischiefs that attended the last.

PASSY, May 1784.

A short ACCOUNT of an EXCURSION through the SUBTERRANEOUS CAVERN at PARIS. By Mr. THOMAS WHITE, Member of the Royal Medical Society of Edinburgh, &c. &c. in a LETTER to his FATHER. Read February 9, 1785.

PARIS, July 29, 1784.

I YESTERDAY visited a most extraordinary subterraneous Cavern, commonly called the Quarries. But before I give you the history of my expedition it will perhaps be necessary to say a few words concerning the *observatoire royal*, the place of descent into this very remarkable cavern. This edifice is situated in the Fauxbourg St. Jacques, in the highest part of the city. It takes its name from its use, and was built by Louis XIV. in 1667, after the design of Claude

Claude Perrault, Member of the Academy of Sciences, and first architect to his majesty. It serves for the residence of mathematicians, appointed by the king, to make observations, and improve astronomy. The mode of building it is ingenious, and admirably contrived, it being so well arched that neither wood nor iron are employed in its construction. All the stones have been well chosen, and placed with an uniformity and equality which contribute much to the beauty and solidity of the whole edifice. It is reckoned to be about eighty or ninety feet in height, and at the top there is a beautiful platform, paved with flint stones, which commands an excellent view of Paris, and its environs. In the different floors of this building, there are a number of trap-doors, placed perpendicularly over each other, and, when these are opened, the stars may be very clearly distinguished, from the bottom of the cave, at noon day.

At this place, I was introduced to one of the inspectors, (persons appointed by the king to superintend the workmen) by my friend Mr. Smeathman, who had used great application and interest for permission to inspect the quarry, and had been fortunate enough to obtain it. For as this cavern is extended under a great part of the city of Paris, and leaves it in some places almost entirely without support, the inspectors are very particular as to shewing it, and endeavour

deavour to keep it as secret as possible, lest, if it should get generally known, it might prove a source of uneasiness and alarm to the inhabitants above. For, what is very remarkable, notwithstanding the extent of this quarry, and the apparent danger many parts of the city are in from it, few, even of those who have constantly resided at Paris, are at all acquainted with it, and on my mentioning the expedition I was going to undertake to several of my Parisian friends, they ridiculed me upon it, and told me it was impossible there could be any such place.

About nine o'clock in the morning we assembled to the number of forty, and, with each a wax candle in his hand, precisely at ten o'clock, descended, by steps, to the depth of three hundred and sixty feet perpendicular. We had likewise a number of guides with torches, which we found very useful; but, even with these assistants, we were several times under the necessity of halting, to examine the plans the inspectors keep of these quarries, that we might direct our course in the right road. I was disappointed in not being able to obtain one of these plans, which would have given the clearest idea of this most extraordinary place. At the entrance, the path is narrow for a considerable way; but soon we entered large and spacious streets, all marked with names, the same as in the city; different advertisements and bills were found,

found, as we proceeded, pasted on the walls, so that it had every appearance of a large town, swallowed up in the earth.

The general height of the roof is about nine or ten feet; but in some parts not less than thirty, and even forty. In many places, there is a liquor continually dropping from it, which congeals immediately, and forms a species of transparent stone, but not so fine and clear as rock crystal. As we continued our peregrination, we thought ourselves in no small danger from the roof, which we found but indifferently propped in some places with wood much decayed. Under the houses, and many of the streets, however, it seemed to be tolerably secured by immense stones set in mortar; in other parts, where there are only fields or gardens above, it was totally unsupported for a considerable space, the roof being perfectly level, or a plane piece of rock.

After traversing about two miles, we again descended about twenty steps, and here found some workmen, in a very cold and damp place, propping up a most dangerous part, which they were fearful would give way, every moment. We were glad to give them money for some drink, and make our visit at this place as short as possible. The path here is not more than three feet in width, and the roof so low, that we were obliged to stoop considerably.

By

By this time, several of the party began to repent of their journey, and were much afraid of the damp and cold air we frequently experienced. But, alas ! there was no retreating.

On walking some little distance farther, we entered into a kind of salon, cut out of the rock, and said to be exactly under the *Eglise de St. Jaques*. This was illuminated with great taste, occasioned an agreeable surprize, and made us all ample amends for the danger and difficulty we had just before gone through. At one end, was a representation in miniature of some of the principal forts in the Indies, with the fortifications, draw-bridges, &c. Cannons were planted, with a couple of soldiers to each, ready to fire. Centinels were placed in different parts of the garrison, particularly before the governor's house; and a regiment of armed men was drawn up in another place, with their general in the front. The whole was made up of a kind of clay which the place affords, was ingeniously contrived, and the light that was thrown upon it, gave it a very pretty effect.

On the other side of this hall, was a long table set out with cold tongues, bread and butter, and some of the best Burgundy I ever drank. Now every thing was hilarity and mirth; our fears were entirely dispelled, and the danger we dreaded, the moment before, was now no longer thought of. In short, we were all in good spirits again,

again, and proceeded on our journey about two miles further, when our guides judged it prudent for us to ascend, as we were then got to the steps which lead up to the town. We here found ourselves safe, at the *Val de grace*, near to the English benedictine convent, without the least accident having happened to any one of the party. We imagined we had walked about two French leagues, and were absent from the surface of the earth, betwixt four and five hours.

After we had thanked the inspectors and guides for their very great civility, politeness, and attention, we took our leave to visit the English benedictines convent, in whose court yard, and within a few yards of their house, the roof of the subterraneous passage had given way, and fallen in, the depth of one hundred and ninety three feet.

Though there were some little danger attending our rash expedition (as some people were pleased to term it) yet it was most exceedingly agreeable, and so perfectly a *nouvelle scene*, that we were all highly delighted, and thought ourselves amply repaid for our trouble.

I regretted much that I did not take a thermometer and barometer down with me, that I might have had an opportunity of making some remarks, on the temperature and weight of the air. Certainly, however, it was colder at this time than on the surface of the earth.

But

But Mr. Smeathman informed me, that when he descended the last winter, in the long and hard frost, he found the air much more temperate than above ground, but far from warm. Neither, however, had he a thermometer with him. I lamented too that I had not time to make more remarks on the petrefactions, &c.

Mr. Smeathman observed, that when he descended, he found a very sensible difficulty of breathing in some of the passages and caverns, where the superincumbent rock was low, and the company crowded. This no doubt was much increased by the number of persons and of wax lights, but he does not apprehend that the difficulty would have been so great in rooms of equal dimensions above ground. We remarked too, when we descended, that there was, in some degree, an oppression of respiration throughout the whole passage.

There were formerly several openings into the quarries, but the two I have mentioned, viz. the *Observatory* and the *Val de Grace*, are, I believe, the only ones left; and these the inspectors keep constantly locked, and rarely open them, except to strangers particularly introduced, and to workmen who are always employed in some part by the King.

The Police thought it a necessary precaution to secure all the entrances into this cavern, from its having been formerly inhabited by a famous
gang

gang of robbers, who infested the country for many miles round the city of Paris.

For the origin of this quarry, I could not, on the strictest inquiry, learn any thing satisfactory; and the only account I know published, is contained in the *Tableaux de Paris Nouvelle edition, tom premier, chapitre 5^{me}. page 12^{me}.*

“ Pour batir Paris dans son origine, il a fallu
 “ prendre la Pierre dans les Environs; la con-
 “ sommation n’en a pas été mince. Paris
 “ s’agrandissant on a bâti insensiblement les
 “ Fauxbourgs sur les anciennes Carriers, de
 “ sorte que tout ce qu’on voit en dehors, man-
 “ que essentiellement dans la terre aux fonde-
 “ ment de la Ville; de la, les Concavites effray-
 “ antes, qui se trouvent adjoin’d’hui sous les
 “ maisons de plusieurs quartiers; elles portent
 “ sur les Abymes. Il ne foudroit pas un choc
 “ bien considerable, pour ramener les pierres au
 “ point d’ou on les a enleves avec tout d’effort.
 “ Huit personnes ensevelies dans un Gouffre de
 “ cent cinquante Pieds de Profondeur, et quel-
 “ ques autres accidens moins connus, ont excité
 “ enfin la vigilance de la Police, et du gou-
 “ vernement; & de fait, on a etagé en silence
 “ les edifices de plusieurs quartiers, en leur
 “ donnant dans ces obscurs Souterreins un apui
 “ qu’ils n’avoient pas.

“ Tout le Fauxbourgs Saint Jacques, la Rue
 “ de la Harpe, & meme la Rue de Tournon,
 “ portent

“ portent sur d'anciennes Carrières, & bâties
“ bati des Pilaftres pour soutenir le Poids
“ Maisons. Que de matiere a reflexion. Et
“ confiderant cette grande ville formée, & en-
“ tenue par moyens absolument contraires ! les
“ Clochers, ces Voutes des temples, autant
“ de signes, qui difent a l'oeil ce que nous
“ voyons en l'air manque fous nous Pieds.”

“ For the first building of Paris, it was neces-
“ fary to get the stone in the environs, and the
“ consumption of it was very confiderable. As
“ Paris was enlarged, the suburbs were infenfibly
“ built on the ancient quarries, so that, all that
“ you fee without is essentially wanting in the
“ earth, for the foundation of the city : hence
“ proceed the frightful cavities, which are at
“ this time found under the houses in several
“ quarters. They stand upon abyffes. It would
“ not require a very violent fhock to throw back
“ the stones to the place, from whence they
“ have been raised with so much difficulty.
“ Eight men being fwallowed up in a gulph one
“ hundred and fifty feet deep, and some other
“ less known accidents, excited at length the
“ vigilance of the Police and the government,
“ and, in fact, the buildings of several quarters
“ have been privately propped up ; and by this
“ means, a support given to these obscure sub-
“ terraneous places, which they before wanted.

“All the suburbs of St. James’s, Harp-street,
 “ and even the street of Tournon, stand upon
 “ the ancient quarries; and pillars have been
 “ erected to support the weight of the houses.
 “ What a subject for reflections, in considering
 “ this great city formed, and supported by
 “ means absolutely contrary! These towers,
 “ these steeples, the arched roofs of these temples
 “ are so many signs to tell the eye, that what
 “ we now see in the air, is wanting under our
 “ feet.”

*A DESCRIPTION of a NEW INSTRUMENT for mea-
 suring the SPECIFIC GRAVITY of BODIES. By
 Mr. WILLIAM NICHOLSON, in a LETTER to
 Mr. J. H. MAGELLAN, F. R. S. Reg. Acad.
 Petropol. & Paris. Corresp. &c. Read May 4,
 1785.*

DEAR SIR,

ACCORDING to my promise, I transmit to
 you an account of the Instrument I have
 constructed for the easy and exact finding the
 specific gravities of bodies. It appears to me to
 be as perfect, as the nature of a floating instru-
 ment of this kind will admit of; and, for that
 reason, I presume it will not be impertinent to
 mention

mention previously what has been done in this way.

It seems to follow from a passage in Boyle's account of a new Essay Instrument, * that the Hydrometer, or Areometer was first invented by that great philosopher. The essay instrument here mentioned, was intended for the hydrostatical proof of metals, and was adapted to serve chiefly for guineas. It consisted of a ball, somewhat less than an hen's egg, with a stem of four or five inches in length, soldered to the upper part, and a bent wire or stirrup beneath, to place the coin upon. A slit piece of brass, with a lateral screw to hold the coin tight, though in fact conducing more to the ease than accuracy of the experiment, is mentioned by the author, as being preferable to the stirrup: and, to extend the use of the instrument, he proposes that the ball be made large, and provided with a contrivance for occasionally changing the quantity of ballast applied beneath the ball.

Boyle's instrument was intended to be used in water, and, consequently, the graduations of its stem denoted certain invariable weights. But when the hydrometer is to be used in various fluids, it diminishes the accuracy of the results,

* Lowthorp's Abridgement of the Philosophical Transactions, vol. I. p. 604. Or Boyle's Works in 4to. edit. London, 1772, vol. IV. p. 204.

if those spaces be taken for absolute weights; or, at all events, it brings forward a rather intricate consideration of the relation which the bulks of the spaces, or parts of the stem, have to the whole immersed part. This appears to have been the inducement that led M. G. Fahrenheit * to add a small dish or scale to the top of the upper stem, which, instead of graduations, had only a single mark that, in all cases, was to be brought to the surface of the fluid, by means of weights added in the said scale.

Mr. Clarke, † who in the year 1730 published an account of an hydrometer, does not appear to have been apprised of what had been done before by Boyle and Fahrenheit. For he speaks of his own instrument as a new invention, though it does not differ from that of Boyle, except in having a great number of ballast weights to be screwed occasionally to the lower stem, instead of depending on the graduations of the upper stem; and he affirms, that the specific gravities of fluids cannot be found without a great deal of trouble, though it is certain that they may be found with greater ease, and much more accuracy, by that of Fahrenheit, than by his own. Clarke's hydrometer, with weights adapted to

* Reid and Gray's Abridgment of the Phil. Transf. vol. VI. part I. p. 294.

† Ibid. vol. VI. part I. p. 295.

allow for the diminution of specific gravity, which arises from the thermometrical expansion of fluids, is used by the officers of excise.

This hydrometer is inferior to Fahrenheit's in two respects. In the first place, either a bubble of air, or a portion of the fluid, will lie hid in that part of the cavity of the ballast weight, which is not filled by the screw; and it is of very different consequence, which of the two is there. And secondly, the weights acting on the instrument, by their residual gravity, will not be constant; or, in other words, an additional weight will be accompanied by an addition to the bulk of the immersed part of the instrument: and, in the case where the specific gravity of the liquid is not given, but required, it will not be easy to determine how much the operation of the one is counteracted by that of the other. However, though this last consideration evinces that the instrument is not fit for general use, yet it is accurate for the trial of ardent spirit, or any other particular liquid, when the weights are adjusted by experiment to the intended use.

Posterior to these, there have been several attempts to improve the hydrometer, but as they have been aimed chiefly to render it more perfect or convenient, with respect to the single use of proving spirits, it is unnecessary to describe them at large. Among these it is however proper to mention those of Dr. G. Fordyce, and

Mr. Quin. The first is certainly the most perfect instrument we possess, its weights being adjusted to the different specific gravities of spirits, by experiments made at numerous varieties of strength and temperature. The latter having no additional weights, but depending entirely on the graduations of its stem, is much more ready in practice. All its originality consists in its stem being the frustum of a cone, whose larger end is uppermost, by which happy contrivance the stem is shortened, and its graduations are all kept nearly equal.

I shall now proceed to describe the instrument I have caused to be made for the general purposes of finding the specific gravities of bodies. Its dimensions are likewise added. *

AA represents a small scale. It may be taken off at D. Diameter $1\frac{1}{2}$ inch. Weight 44 grains.

B a stem of hardened steel wire. Diameter $\frac{3}{16}$ inch.

E a hollow copper globe. Diameter $2\frac{3}{8}$ inches. Weight with stem 369 grains.

FF a stirrup of wire screwed to the globe at C.

G a small scale serving likewise as a counterpoise. Diameter $1\frac{1}{2}$ inch. Weight with stirrup 1634 grains.

* See the figure to which these letters refer in plate II. vol. II.



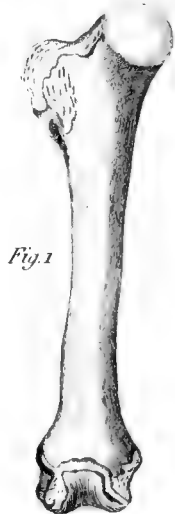


Fig. 1

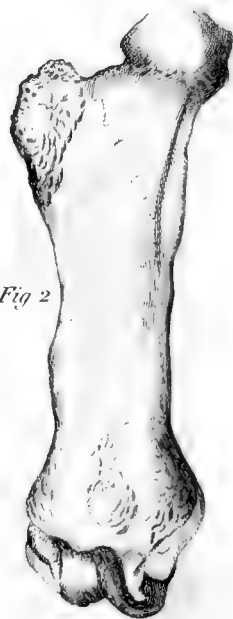


Fig. 2



Fig. 3

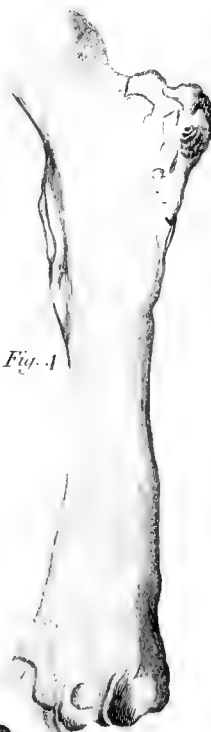


Fig. 4



Fig. 5

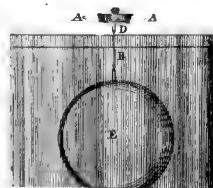


Fig. 6



The other dimensions may be had from the drawing, which is $\frac{1}{3}$ of the linear magnitude of the instrument itself.

In the construction, it is assumed that the upper scale shall constantly carry 1000 grains when the lower scale is empty, and the instrument sunk in distilled water at the temperature of 60° Fahrenheit, to the middle of the wire or stem. The length of the stem is arbitrary, as is likewise the distance of the lower scale from the surface of the globe. But the length of the stem being settled, the lower scale may be made lighter, and, consequently, the globe less, the greater its distance is taken from the surface of the globe; and the contrary. It is to be noted that the diameter of each scale must not be less than the side of a cube of water weighing 1000 grains.

The distances of the upper and lower scales, respectively, from the nearest surface of the globe being settled, add half the side of a cube of water weighing 1000 grains to the distance of the upper scale. This increased distance, and the said distance of the lower scale, may be considered as the two arms of a lever; and, by the property of that mechanical power,

As the number expressing the lower distance

Is to the whole weight above; namely 1000 grains added to the weight of the upper scale,

So is the number expressing the upper distance,
To the lower weight, when the instrument
has no tendency to any one position.

This last found weight must be considerably increased, in order that the instruments may acquire and preserve a perpendicular position.

Add together, into one sum, the weight of the lower scale thus found, the weight of the upper scale and its load, and the estimate weight of the ball and ~~wires~~. Find the solid content of an equal weight of water; and thence, by the common rules of mensuration the diameter of an equal sphere. This will be the diameter, from outside to outside, of the globe that will float the whole.

As this process, and every other part of the present letter, may be easily deduced from the well known laws of hydrostatics; I forbear enlarging on the demonstrative part, and shall proceed to indicate the use of the instrument in the same cursory manner.

To measure the specific gravities, and thermometrical expansions, of FLUIDS. If the extreme length or height of the instrument be moderate, its weight, when loaded, will be about 3100 grains. It is, however, necessary in practice, that its weight should be accurately found by experiment. This whole weight is equal to that of a quantity of distilled water, at the temperature of 60°, whose bulk is equal to that part of
the

the instrument which is below the middle of the stem. If, therefore, the instrument be immersed to the middle of the stem, in any other fluid at the same temperature (which may be done by altering the load) the difference between this last load and 1000 grains, will be the difference between equal bulks of water, and of the other fluid, the weight of the mass of water being known to be 3100 grains. If the said difference be *excess* above 1000 grains it must be added, or if it be *defect* subtracted from 3100 grains: the sum or remainder will be a number, whose ratio to 3100 will express the ratio of the specific gravity of the assumed fluid to that of water. And this ratio will be expressed with considerable accuracy; for the instrument having a cylindrical stem of no more than $\frac{1}{16}$ of an inch diameter, will be raised or depressed near one inch by the subtraction or addition of $\frac{1}{16}$ of a grain, and will therefore indicate with ease such mutations of weight as do not fall short of $\frac{1}{16}$ of a grain, or $\frac{1}{65536}$ th part of the whole. Consequently, the specific gravities of all fluids, in which this instrument can be immersed, will be found to five places of figures.

It is evident, that this instrument is a kind of *thermometer*, perhaps better adapted than the common one, for measuring the expansions of fluids by heat. As the fluid, in the common thermometer, *rises* by the excess of expansion
of

of the fluid beyond the expansion of the glass vessel, so our instrument will *fall* by the excess of the same expansion, beyond the proper expansion of the materials it is composed of.

To *measure the specific gravities* of SOLID BODIES. The solid bodies, to be tried by this instrument must not exceed 1000 grains in weight. Place the instrument in distilled water, and load the upper scale or dish, till the surface of the water intersects the middle of the stem. If the weights required to affect this be exactly 1000 grains, the temperature of the water answers to 60° of Fahrenheit's scale; if they be more or less than 1000 grains, it follows, that the water is colder or warmer. Having taken a note of this weight, unload the scale, and place therein the body, whose specific gravity is required. Add more weight, till the surface of the water again bisects the stem. The difference between the added weight, and the former load, is the weight of the body in air. Place now the body in the lower scale or dish under water, and add weights in the upper scale, till the surface of the water once more bisects the stem. This last added weight will be the difference between 1000 grains, and the weight of the body in water. To illustrate this by an example.

N. B. The specific gravity of lead and tin, (and probably other metals) will vary in the
third

third figure, when the same piece of metal is melted and cooled a second time. This difference probably arises from the arrangement of the parts in cooling more or less suddenly.

The load was found by experiment 999 : 10 grains.
 A piece of cast lead required the additional weight } 210 : 85

Difference is absolute weight in air 788 : 25
 Additional weight when the lead was in the lower scale } 280 : 09

Difference between the two additional weights or loss by immersion } 69 : 24

Hence specific gravity $\frac{788.25}{69.24} = \frac{11384}{1000}$

When the instrument is once adjusted in distilled water, common water may be afterwards used. For the ratio of the specific gravity of the water made use of to that of distilled water being known ($= \frac{b}{a}$), and the ratio of the specific gravity of the solid to the water made use of being also known ($= \frac{c}{b}$), the ratio of the specific gravity of the solid to that of distilled water will be compounded of both (that is, $\frac{cb}{ab}$.)

There is reason to conclude from the experiments of various authors, that they have not paid much attention either to the temperature or specific gravity of the water they made use of.

of. They who are inclined to be contented with a less degree of precision than is intended in the construction here described, may change the stem, which for that purpose may be made to take out, for a larger.

One of the greatest difficulties that attends hydrostatical experiments, arises from the attraction or repulsion that obtains at the surface of the water. After trying many expedients to obviate the irregularities arising from this cause, I find reason to prefer the simple one, of carefully wiping the whole instrument, and especially the stem, with a clean cloth. The weights in the dish must not be esteemed accurate, while there is either a cumulus, or a cavity, in the water round the stem.

I am, DEAR SIR,

Your affectionate humble Servant,

WILLIAM NICHOLSON.

LONDON, *June 1, 1784.*

MEMOIRS of the late Dr. BELL, by JAMES CURRIE, M. D. addressed to the PRESIDENTS and MEMBERS of the LITERARY and PHILOSOPHICAL SOCIETY of MANCHESTER.* Read March 23, 1785.

GENTLEMEN,

THE respect which you have expressed for our late member, Dr. GEORGE BELL, by the Resolutions of the Society, which occasion this address, cannot fail to be highly pleasing to all those who honour his memory. To me this at-

* At a meeting of the Literary and Philosophical Society of Manchester, held February 4, 1784.

1. Resolved, as a mark of respect to the memory of George Bell, M. D. That a translation be made of his Inaugural Dissertation de Physiologia Plantarum—That some brief Memoirs of the Author be prefixed to it, and that the whole be inserted in the Journals of this Society.

2. That James Currie, M. D. the friend of Dr. Bell, and an Honorary Member of this Society, be requested to make the translation, and furnish the Memoirs specified in the above resolution.

3. Resolved, that a copy of these resolutions be transmitted to Dr. Currie, by the acting secretary of the Society.

tention

tion is particularly grateful ; and I should not have been so slow in executing the task which you assigned me, had not long continued sickness deprived me of the power. Now that my strength is in some measure restored, I embrace the earliest opportunity of presenting the translation which you have requested ; and more fully to comply with your wishes, I shall prefix a short history of the life of my much lamented friend.

Dr. BELL was born at his father's estate, in the county of Dumfries, in the autumn of the year 1755. He was the younger son of *Richard Bell of Greenhill*, by *Miss Carruthers of Dormont* ; and, by both sides of the house, was descended of families which claim high antiquity in that country, though little known to fame. The rudiments of his education he received at home, and he was very early distinguished by the quickness of his apprehension, and the general brilliancy of his parts. While he was yet very young, he had the misfortune to lose his father, who died at *Bath* in the year 1766. This loss was, however, in a great measure supplied by the care of his mother, who yet survives to be a blessing to her friends ; and by the counsel and example of his brother, who, though very young, already displayed an uncommon degree of prudence and virtue. By them, Dr. *Bell* was placed at the public school of *Annan*, then conducted by the Rev. Mr. *Wright*, in whose house
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he resided. Here he continued several years, and made a rapid progress in classical literature. In the year 1769, Mr. *Wright* being appointed minister of the parish of *New Abbey*, in the neighbourhood of *Dumfries*, gave up public teaching; but Dr. Bell was continued some time longer in his family, as a private pupil. Under the care of this excellent scholar, he had great advantages. At the time he left him, which was before the completion of his fifteenth year, he had obtained a perfect acquaintance with the Roman classics, a competent knowledge of Greek, he was initiated in the French language, was well skilled in geography, history, and the elements of mathematics, and had commenced a critic in the English Belles Lettres.

In the autumn of the year 1770, he was sent to the university of *Glasgow*, where he continued for one session, in the pursuits of general study. In the latter end of 1771, he was removed to *Edinburgh*, and began his professional studies under the care and direction of his friend and relation Mr. *Benjamin Bell*, whose name is now well known in the medical world. At this university he continued till the summer of the year 1777, when he obtained the degree of Doctor of Medicine, and published the Inaugural Dissertation, to which you are about to give a place in your records. During this long period, Dr. Bell had time to apply himself, not only to the various

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ous branches of medicine, but to the different departments of philosophy and polite literature, necessary to a plan of liberal and general education. As his application was great, his acquirements were very considerable; and he was so happy as to attract the notice of several persons eminent for science and learning. Of this number, was the present learned Professor of Botany in *Edinburgh*, Dr. Hope, who early discovered his acute and enterprizing genius, and distinguished him by his patronage and counsel. Of this number likewise was the celebrated Dr. *Cullen*, who honoured him with his particular friendship, and introduced him to the late Lord *Kames*, in a manner which was extremely flattering. His Lordship, when engaged in the composition of the work, which he afterwards published under the title of, *THE GENTLEMAN FARMER*; applied to Dr. *Cullen* for information on some subjects connected with the philosophy of vegetation. The learned professor, being deeply engaged with other subjects, referred him to Dr. Bell, then in his twentieth year, whom, on that occasion, he introduced to his Lordship. An acquaintance, thus begun, was matured into intimacy, and Dr. Bell spent a considerable part of one or two autumn vacations at the country seat of this venerable old man, in the south of *Scotland*. Lord *Kames* mentioned him with honour, in
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the work to which I have alluded, and entertained a particular regard for him to the end of his life. When he made the tour of *France*, the letters of introduction, which he procured from this illustrious philosopher, were of the greatest service; and he was likewise much indebted to his friendship, when he afterwards settled as a physician at Berwick on Tweed.

While Dr. Bell was pursuing his studies at *Edinburgh*, his elder brother, to whose most affectionate care he was highly indebted, met an untimely and unexpected fate. In the autumn of the year 1776, he perished in bathing in the river Kirtle, near the bottom of his own garden. This admirable young man was bred to the Scotch law. His talents and his virtues made his life most honourable, and his early death most deeply lamented.

Soon after his graduation, Dr. Bell removed from *Edinburgh* to *London*, with the view of completing his education, and after a winter's residence there, he passed over into *France*. At this time, he relaxed from the severity of his studies, and mingled more than might, from his former habits, have been expected, in the scenes of gaiety and pleasure with which *Paris* abounds.

In the latter end of the year 1778, he returned to *Scotland*. Some part of that, and the succeeding winter, he spent in *Edinburgh*, and, during

the rest of his time, he in general lived with his mother and sisters at his paternal estate. While there, besides the gratis exercise of his profession among his friends and neighbours, he was much engaged in the study of the French and Roman classics, and particularly, of the works of *Virgil*, of whom he was an enthusiastic admirer. In this interval, he composed two MSS. volumes of criticism on the *Æneid*.

In the spring of the year 1780, he settled, as a physician, at Berwick on Tweed, with very general and powerful recommendations; and, in less than a year, he fell into the first practice in that quarter. But, it having been represented to him, that he might have a larger field for the exercise of his professional talents at *Manchester*, he removed thither in the month of March 1781.

It is not necessary to detail the incidents of the remaining part of his life. On this subject you cannot want information. He was admitted as a member into your Society, soon after his arrival in *Manchester*, and he continued such till his death. During this period, you all, probably, knew him, and it becomes you, better than me, to estimate the degree of regard and esteem, with which he was honoured. It only remains, that I give a short account of the concluding scene, to which, by the privilege of friendship, I was a mournful witness, and on
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which I reflect, with mingled sensations of pain and pleasure, which I forbear to describe.

On the 20th of last January, he was seized with the symptoms of a fever, which, from the first, he apprehended would prove fatal. He requested the advice of his friends Dr. *Manwaring* and Dr. *Percival*, and they attended him, through the whole illness, with the utmost kindness and assiduity. But, notwithstanding every assistance which medicine could bring, the disease proceeded with most unfavourable omens. He clearly foresaw his approaching fate, and prepared for the moment of dissolution, with unshaken fortitude. On the eighth day he became delirious; and from this time forwards he possessed his reason, by intervals only. A vigorous constitution supported him, under a violent disease, till the evening of the fourteenth day, when, after having sustained many severe conflicts, his strength became utterly exhausted, and he expired without a struggle.—In this manner was terminated the life of a man, who had virtues to procure the love, and talents to command the respect, of his fellow-creatures; and who, by an affecting, though not uncommon, dispensation of Providence, was cut off in the beginning of his career.

Dr. Bell was endued by nature with a firm undaunted mind, a vigorous understanding, and a feeling heart. All his impressions were strong,

and his convictions deeply rooted. From these, and from these only, he spoke and acted. He was utterly free from every species of dissimulation or deceit. His conduct was always direct, and his purpose evident. His deliberations were more swayed by what he himself thought right, than by what was likely to be thought right by others; and when his determination was once made, he was not easily diverted from it, either by fear or favour. His adherence to truth was strict and uniform, even from his early youth. His spirit was too elevated to submit to falsehood, from whatever source it might be supposed to arise, whether from the suggestions of vanity, the impressions of fear, or the dictates of malice. His humanity was pure and unaffected. No man did a kind action with less consciousness of merit, or less purpose of gaining applause. His passions were warm, his affections strong, his sense of honour nice, his spirit, when provoked, high and indignant. In the more intimate relations of life, he was greatly beloved; in many of the qualities necessary for friendship, he has seldom been equalled. Through the whole of his conduct there appeared a strain of manly sincerity. From his cradle to his grave, he, perhaps, never, on any one occasion, sacrificed reality to appearances, or courted applause from others, which was not justified by the approbation of his own heart.

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These high endowments do not often appear without their kindred defects. A fearless temper, and an open heart, are seldom strictly allied to prudence, and are apt to inspire a contempt of appearances, which may have serious consequences in the business of life. That this was instanced in Dr. Bell, those who loved him best are forced to allow. He was not always sufficiently attentive to the decorum of manners: he was too much disposed to break through those restraints, which a necessary ceremony has imposed on the intercourse of society. Free from affectation himself, he was quick in discerning it in others; and he seldom allowed any thing which bore its resemblance, to pass unnoticed, even in those for whom he entertained the highest esteem. The consequence which vanity often assumes, and which benevolence sees and admits, he was too much inclined to expose. This bias of mind appeared before he was eight years of age. At that time, the uncommon liveliness of his temper, and quickness of his apprehension, made him universally admired, as a child of extraordinary talents. Every folly of his imagination was encouraged, and the disposition to which I have alluded, grew up into a habit, which great tenderness of heart and strength of judgment could never effectually overcome. The features of his character were indeed strongly marked throughout, from his early

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youth. When yet a boy, he had the same independence of spirit and originality of mind, which marked his riper years.

Failings, such as his, have their most unfavourable effects in general intercourse. In the eye of friendship they appear of little account, when weighed against a liberal, cultivated, and vigorous mind, and a temper brave, generous, and sincere.

Dr. Bell acquired knowledge with remarkable facility; but he did not communicate it with equal ease. This was chiefly owing to early habits of verbal and grammatical criticism, in which he had greatly indulged. He was extremely nice in his choice of words; he would use no expressions that were not exactly fitted to his ideas, and, in his dislike of every thing strained or affected, he had declared war against some of the natural ornaments of speech. His reading was extensive, and his learning various. In every thing which related to his profession, he was minutely informed. His education had afforded him every opportunity of improvement; his application was great, and his acquirements were proportionably valuable. In classical literature he had few equals; and, in historical and philosophical knowledge, he had not many superiors.

The qualities of Dr. Bell's mind required a state of action. He was eminently fitted for
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situations of difficulty or danger; and had his lot been cast differently, the enthusiasm of his spirit, and the strength of his faculties, might have enrolled his name in the list of those which go down, to future ages, with honour and applause. It was his misfortune, that his situation did not always present objects of sufficient importance to excite his attention, and call forth his faculties; and that, like many other men of genius, he was often unable to originate those literary exertions, which sometimes bring fame, and which generally bring happiness. His spirits indeed were not equal. He was often lively, chearful, and familiar, and sometimes grave, inattentive and reserved. Circumstances, which it would be painful and improper to relate, contributed to throw some degree of gloom over his latter days. But he was naturally subject, at times, to those ebbings of the mind, as an admired writer expresses himself, which generally accompany great sensibility; a state, from which the transition is sometimes more easy to levity and mirth, than to the sober exercises of reason.

It is common to expect, even in the more minute parts of the conduct of men of allowed superiority of talents, some marks of intention and design, by which such superiority might be indicated. But this is, I think, an error. The characteristic of genius is simplicity. A lofty spirit submits, with difficulty, to restraint or disguise,

guise; and the higher emotions of the mind are seldom compatible with a nice attention to little things. It is, however, to be lamented, that men of great endowments are often deficient in that self-command, which should give regularity to conduct, and steadiness to exertion. But let us not too hastily condemn them. The powers of genius impose the severest task on the judgment. The imagination, in which they reside, must always be strong; the sensibility by which they are attended, must often be wayward. To restrain, to excite, and to direct, the exertions of a mind so constituted, according to the dictates of reason, must frequently produce a most painful warfare: and, if to succeed in such contests be not always given to the strong, let the weak rejoice, that they are seldom called to the encounter.

Years and experience would, most probably, have remedied, in a great measure, the defects in Dr. Bell's character; and, as he became more fully known, it may be presumed, that he would have acquired a degree of reputation suited to his great integrity and abilities. Yet it cannot be denied, that a temper so open, and a conduct so little affected by the opinions or prejudices of others, were not perfectly calculated for success in a world, in which the most honest heart must often be veiled, and the loftiest spirit must sometimes bend.

Such,

Such, Gentlemen, was the man, whose memory you wish to preserve in the Records of your Society. I knew him better than any person living, and I loved him more than I shall attempt to express. I have not, however, dealt in unmixed eulogy, which sometimes may amuse the living, but which can never characterise the dead. It belonged to him I have attempted to commemorate, to be as jealous of undeserved praise, as of undeserved censure; and I have endeavoured to delineate his character, in such a manner, as his magnanimous spirit would have approved. I have not, knowingly, extenuated his faults; and you will not believe, I have set down ought in malice. What would it avail me to deviate from the truth? The voice of censure cannot pierce the grave, nor flattery soothe the ear of death.

J. C.

LIVERPOOL, *September 30, 1784.*

*A TRANSLATION of Dr. BELL'S THESIS, de PHY-
SIOLOGIA PLANTARUM. By JAMES CURRIE,
M. D.* Read March 30, 1785.*

DIFFERENT parts of nature have drawn the attention of different philosophers. While some men of the greatest genius have employed themselves in the study of their own species; others have been diligently engaged in investigating the properties of the inferior classes of animals. Nor are those to be placed in the lowest class of philosophers, whose time and attention are engrossed by that immense portion of nature, the Vegetable Kingdom; though, it is to be regretted that, in general, their observations have been directed more to the external form of plants, than to their internal structure.

The knowledge of the internal structure of vegetables unfolds their œconomy, and, from a discovery of this, not only botany, but agriculture, might receive great improvement. But

* The original was published at Edinburgh, June 1777, and dedicated to doctors CULLEN and HOPE, in language, which expresses a high admiration of their talents and virtue, and a deep sense of gratitude for the *favours* received from them, by the AUTHOR,

this subject is as difficult, as it is important, and, as yet, it is not precisely understood, even by the most curious observers. I am led to engage in it more by the pleasing nature of the study, than the hope of surpassing those who have gone before me; and I purpose, in the following Essay, to confine myself to a few remarks on the structure, life, and functions, of vegetables.

It is proper to premise, that if the anatomy of plants be not demonstrated throughout, with all the clearness that could be wished, this arises from their containing parts of such a degree of minuteness, that they elude the human sight. The nature of these must therefore frequently be inferred from analogy only, which is often fallacious. But many things have been ascertained on this subject, and with these I shall begin.

On making a transverse section of a tree, it appears to consist of three distinct parts—the bark—the wood—and the medulla, or pith.

1. The bark consists of two parts—the cuticle, and the true bark. The cuticle of plants affords an external covering to all their parts. It consists of numerous layers, easily separable from each other, and of which the fibres are circular.*

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* Dr. Hill, by the use of magnifying glasses, first discovered the cuticle to be an organized body, containing longitudinal vessels, and vesicles, &c. He however thought, the cuticle was formed merely by the hardening of the superficies of the true bark, when exposed to the external air.

The true bark may be considered as a congeries of cellular substance, in which are placed two kinds of organs, the *vasa propria*, or the vessels peculiar to the plants, and the longitudinal fibres. Of the use of these, nothing can be said at present.

2. On removing the bark, the wood appears. Its substance is denser than the bark, and its structure more difficult to be demonstrated. But it has been discovered likewise to contain *vasa propria*, and longitudinal fibres, and, besides these, large vessels with spiral coats, which run from one end of the tree to the other, and are denominated *vasa æria*. Between the wood and the pith lies a green coloured substance, first accurately described by Dr. *John Hill*, and by him affirmed to contain all the parts of the plant in embryo: he gave it the name of *Corona*.

3. In the centre of the tree resides the pith, which, in young plants, is very abundant. As they approach to maturity it grows drier, and appears in a smaller quantity; and, in very aged trees, it is entirely obliterated. Its substance is cellular, and, according to the author just men-

air. In this he was mistaken, because it is found in the heart of fruits, covering the seed, and because *Du Hamel*, and Dr. *Hope* found, that, when the cuticle is removed, and the accession of the air prevented by wax-cloth, this covering is nevertheless in a little while restored.

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tioned, it is of a similar structure in all plants. These are the solid parts of vegetables.

But there are likewise fluids, or juices in vegetables: and these are of two kinds. The one is of the same nature in all the variety of vegetables: the other varies according to the different plants in which it exists. The former, which is called the *succus communis*, when collected early in the spring, from an incision made in the birch or vine, differs little from common water.* The latter, which is named the *succus proprius*, possesses various properties in various plants, and gives to each its sensible qualities. These two juices never mingle with each other in the tree, and the latter is found in the *vasa propria* only.

It is not yet ascertained, whether the juices of plants are transmitted through vessels, or cellular substance. Each side of the question has had its advocates, who have supported their respective opinions with probable arguments: but it is to be regretted, that, on so

* It has, however, been alledged to contain a saccharine matter in some trees, as in the maple, &c. It has likewise been supposed to contain an acid. But, in various experiments which Dr. Bell made on it, he found nothing in it of either kind; and therefore, where such appearances have taken place, he supposed them to arise from an adventitious mixture of the sap, and the *succus proprius*. J. C.

interesting a subject, no conclusion can be formed from the actual dissection of vegetables. To me it seems most probable, that all the fluids of plants are transmitted through vessels, for the following reasons. 1. The existence of *vasa propria*, and *vasa aëria*, is discoverable by the naked eye, and made still more manifest by the microscope. That *succus proprius* and air are contained in these is evident, and therefore analogy leads us to believe, that the *succus communis* is also contained in vessels. 2. Secretion, of which vegetables have undoubtedly the power, is in no instance, that we know of, performed without the action of vessels. 3. An experiment, made by Dr. Hales, seems clearly to prove, that the sap is contained within its own vessels, and does not fortuitously pervade every interstice of the plant. He fixed an instrument round the stem of a vine, by which its contractions and expansions could be accurately measured; but he found no difference in the circumference of the trunk, when the tree was full of sap, and when it was entirely without it, although the instrument employed was so nice, as to detect a variation of the hundredth part of a finger's breadth. If the sap had been transmitted, without vessels, through the cellular substance, this, on the withdrawing of the sap, would have been compressed, and
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of course the stem of the tree would have contracted itself into a smaller compass. *

We are now to consider in what direction the fluids of plants are transmitted.

I. *Of the Course of the Succus COMMUNIS, or Sap.*

Botanists have made many experiments to ascertain the course of the sap. Early in the spring, when the sap begins to flow, incisions have been made in the trunk and branches of trees, as far as the pith; and, in such cases, it has been constantly found, that a larger quantity of sap flowed from the superior, than from the inferior margin of the incision. This circumstance led to the opinion, that in the beginning of the spring, great quantities of moisture are absorbed by trees from the atmosphere, and hence the source of the abundance of sap.† But this conclusion, I found to disagree with the phe-

* To determine this question absolutely, it may seem, that the most certain and obvious method would be by injections, the great source of our knowledge of the anatomy of animals. They have been employed by *Bonnet*, *Dr. Hope*, and others, but they have failed. They rise a considerable way into plants, but as, in different cases, they take different courses, from this, and other circumstances, there is reason to believe, that their course, and that of the sap, are materially different from each other. J. C.

† *Dubamel* and others. See *Phyf. des Arbres*, Tom. I. p. 67.

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nomena of nature from the two following experiments. 1. Having made incisions of various heights into the stem, of several plants, I immersed their roots into a decoction of log-wood. The roots absorbed the coloured liquor, which at length began to flow from the superior, and not from the inferior, margins of the incisions; nor had the liquor extended itself much upwards, beyond the margin of the incision from which it was discharged.

2. In the season when the sap flows most abundantly, called the bleeding season, a deep cut was made into the branch of a growing vine, and the greatest quantity of sap was discharged from the upper margin of the incision: but a branch of the same tree, cut in the same manner, being inverted, the sap flowed most copiously from the other margin of the incision, which of course was now that next the root. On the other hand, many experiments may be brought to prove directly, that, in the bleeding season, the sap ascends from the roots towards the branches; the following however may suffice.

1. Early in the spring, when little or no sap had as yet entered the plant, Dr. *Hope* made a number of incisions, of different altitudes, into the root and stem of a birch. As the sap rose, it first flowed from the superior margin of the lowest incision, and then, in regular succession, from the upper margins of the other incisions
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till at last, it reached the highest. 2. If, in the beginning of the bleeding season, before the sap is found in the stem or branches, an incision be made in the root of a vine, a considerable flow of sap will follow the wound. 3. The quantity of sap is very generally proportioned to the humidity of the soil.*

II. *Of the course of the SUCCUS PROPRIUS.*

When a portion of the bark and wood of the pine, is cut from the stem, the *succus proprius* flows in considerable quantity both from the upper and under margin of the incision. Hence it occurred to botanists, that this juice might have little or no motion, and that its efflux from such an orifice might depend entirely on its being freed from the pressure of the bark and

* It may still be asked, Why the sap flows most from the superior margin of each incision, supposing it to arise from the roots? The incision, it is said, hurts or destroys the energy of the sap-vessels for a considerable way below, whence the sap is not propelled upwards, against its own weight, and the pressure of the atmosphere now admitted. From the divided vessels, it passes by a lateral communication (for there are sap-vessels in every direction) into those undivided, and when it has got above the incision, it again passes laterally into the divided vessels; and falling downwards, from its own gravity, a want of continuity of vessels, and the diminished pressure of the atmosphere, it flows from the superior margin of the incision. J. C.

wood. But I cannot accede to this opinion : for although in the beginning, the *succus proprius* flows from both margins of the incision, in a little while, as I have observed, it is discharged from the superior margin only. This observation in itself is not however decisive. For it may be supposed, that the liquor flows more copiously from the superior margin, because the pressure of the air is less upon it, than on the inferior, and because the liquor itself is disposed to fall downwards by its gravity, in the same manner as the *succus communis*. That I might put this matter out of doubt, I placed the branch of a pine in a horizontal position, and another branch I inverted, so that its branches were turned towards the earth. In these situations, I cut a portion of the bark and wood from each, and, in both instances, the *succus proprius* flowed only from those margins of the incisions which were farthest from the roots. Hence it appears clearly, that the course of this juice, in its vessels, is never from the roots towards the branches, but always in the contrary direction.*

Besides the vessels of the *succus proprius*, and those conveying the sap, a third kind are found

* From the experiment above recited, it appears, that the flow of the proper juice is not influenced in the same degree, as that of the sap, by an alteration in the posture of the vessel from which it issues. To what cause this is owing does not clearly appear. J. C.

in vegetables, named air-vessels, or *vasa aëria*. These are chiefly situated in the wood, leaves, and petals; but are wanting in the bark of trees, and in the herbaceous plants. They are formed by a number of small filaments, spirally rolled up, so as to form a cavity in the middle. The name of *vasa aëria* has been given them, because they are empty of liquor, and because a great quantity of air is certainly found in the wood of plants, where these vessels are chiefly placed, and where there is no peculiar organization. They are supposed to be the instruments of respiration in vegetables; but in what manner this function is performed, is not clearly understood.

I. Some imagine that the air enters the plants by the roots, in a non-elastic state, and gradually recovers its elasticity in its passage through them. To this opinion it is objected. 1. That a great number of *vasa aëria* is found in the roots of trees, where the juice has undergone little or no circulation, and where of course little or no air can be supposed to be evolved. 2. That the roots are very incommodiously placed for absorbing air, being generally so deeply buried in the earth, as to be entirely out of its reach.

II. Others suppose the air is absorbed by the leaves, and thence carried into the body of the plant. There are indeed many air-vessels in the

leaves, and these seem necessary for receiving the air evolved by circulation, which at length passes off with the perspirable matter. But if the air were absorbed by the leaves, and descended towards the roots, its motion would be opposite to that of the sap, and, instead of assisting, would obstruct its progress. It is commonly believed, that after the air has entered vegetables, it is expanded or contracted, according to the variations of the temperature of the atmosphere, and in this way assists the ascent or descent of the fluids. To this opinion it may be objected. 1st. That the air-vessels in the roots, where the sap is first put in motion, are so deep seated, that the changes in the heat of the atmosphere cannot affect their temperature. 2. That the common juice ascends, and the proper juice descends, whether the air be hot or cold. 3. That the pressure of the air-vessels on those which contain juice, will not more promote than obstruct the motion of the fluids in a given direction, unless the vessels which include them contained valves, and in this case these fluids could not have a retrograde motion. Let us look for some more probable opinion.

Dr. Hill has demonstrated, that the cuticle of plants is an organized substance, containing vessels. In trees and shrubs, these vessels have an external opening; but in the herbaceous plants this is wanting. Trees and shrubs only are possessed

possessed of *vasa aëria*, and, when a plant is placed under the exhausted receiver of an air-pump, the air enters through the cuticle, and only issues from the wood, in which the *vasa aëria* are situated. From these circumstances taken together, and considered attentively, we have reason to conclude, that the air's proper entrance to the *vasa aëria* is through these cuticular vessels. Thus, in the early part of the spring, the gentle heat expands the mouths of these vessels, before contracted by the winter's cold. Into these orifices, the external air rushes and presses down to the roots. To these it gives energy, as it does to the moving fibres of animals; and, by its pressure, it may assist in propelling the juices upwards. An additional quantity of air is evolved by the internal motions of the plant, and the whole passes off with the perspirable matter. In this way, there seems to be a circulation of air through plants, assisting and assisted by the powers which move the juices.

The two following facts confirm the above opinion, and, at the same time, shew, that in plants, as well as animals, impeded respiration impedes the motion of the fluids, and interrupted respiration destroys it.

1. In the winter season, I covered several young trees with varnish, and at the same time wrapt them in wax-cloth, leaving the tops of

the branches only exposed to the air. They remained in this situation during the following summer, when some of them lived, though in a languid state, and put out a few leaves; but those from which the air had been more accurately excluded, died without a single exception.

2. Trees over-grown with moss have few leaves, weak shoots, and no fruit. The practice of gardeners is therefore to be commended, who, in the spring, strip the moss from the bark of aged trees, and thus admitting the accession of the air, restore them to verdure and fruitfulness.

Having considered the course of the fluids in vegetables, we next proceed to examine the powers by which these fluids are moved.

Capillary attraction has generally been accounted the cause of the motion of the juices of plants; and the permanence of the action of this power has been supposed to depend on the evaporation from the leaves. Of late years, indeed, botanists have ascribed to plants a vital power, which they believe assists the flow of the juices; and to this opinion I accede, for the following reasons. 1. The descent of the juices, that is, their return from the branches to the roots, cannot be explained without the supposition of a vital power regulating the motion. A flow of fluids, through capillary tubes, will only take place, when the resistance, at the one end, is diminished. This might account for the

the rising of the sap, when warmth is applied to the leaves, but cannot account for its descending in the same circumstances, that is, when the atmosphere is warmer than the earth. But this takes place constantly, with respect to the *succus proprius*, and it is probable, that part of the sap has the same course, both in the day and night.

2. The exertions of many plants, on the application of stimuli, afford another argument in support of their muscular power, and the spontaneous motions of other plants confirm the same opinion. 3. Light admitted to plants, increases their perspiration, and causes a leaf, before inverted, to resume its natural position.* The influence of darkness contrasts these effects, and it produces, what is called, sleep in plants, although the heat of the atmosphere be not diminished. These facts seem to prove the irritability, or muscular power of vegetables. 4. If the fluids of plants are conveyed through vessels, as I have already rendered it probable they are, can we suppose these tubes to be of so small a diameter, as, by capillary attraction alone, to raise the juices from the roots to the summits of the loftiest trees? 5. On the supposition of the fluids being moved entirely by capillary

* *Miller* in the *Philosophical Transactions*, and *Bonnet*, Sur l'usage des feuilles.

attraction, how happens it, that the sap of the vine flows from an incision made in the spring, and not from one made in summer? In this case, as the vessels remain the same, and the heat is at least not diminished, the efflux of sap ought to be equally copious in summer as in spring. 6. Capillary tubes, filled with liquor, do not discharge their contents when broken across. But from the stem of a vine, cut transversely, a large quantity of fluids is discharged, as has been demonstrated by Dr. Hales. 7. The analogy between vegetables and animals, which was formerly pointed out, gives a reasonable presumption, that the fluids of both are moved by similar powers. In animals, the powers of circulation are respiration and muscular action: of those powers in plants we have already treated, and what has been said on the subject, seems to shew, that the motion of the juices in plants is rather to be ascribed to them, than to capillary attraction.

I might draw some arguments, in addition to these, from some experiments I have lately made, to ascertain the effects of air impregnated with various effluvia, of light, and of saline solutions, on the growth and qualities of vegetables; but these, being as yet incomplete, I forbear to detail. In general, however, it appeared, that there are particular substances
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which increase the growth of plants, by acting as stimuli on their moving fibres.*

There are some other functions which belong to vegetables, of which I shall now endeavour to give some account.

Plants, as well as animals, perspire, and, in both cases, this function is essential to health. By the experiments of Dr. *Hales*,† and M. *Guettard*,‡ it appears, that the perspirable matter of vegetables differs in no respect from pure water, excepting that it becomes rather sooner putrid. The quantity perspired varies, according to the extent of the surface from which it is emitted, the temperature of the air, the time of the day, and the humidity of the atmosphere. As the leaves form the greatest part of the

* The experiments here alluded to were made, to determine the influence of light, of fixed air, of inflammable air, and of the vapour which arises from the putrefaction of cabbage leaves, on the growth of vegetables. Dr. *Bell* likewise tried the effects of some saline bodies, of which I do not recollect the particulars. When the different vapours were applied to growing vegetables, the light was accurately excluded. Nevertheless, in that to which fixed air was applied, there was some degree of taste and smell; and where the inflammable air was used, there was likewise a tinge of the natural colour. He often thought of repeating these experiments, but death prevented this, and many other schemes. J. C.

† Statical Essays, vol. I. p. 49.

‡ Mem. de l'Academie des Sciences, 1748.

surface,

surface, it is natural to suppose, that the quantity of these will very materially affect the quantity of the perspiration. Accordingly, the experiments of *Dr. Hales* have ascertained, that the perspiration of vegetables is increased or diminished, chiefly, in proportion to the increase or diminution of their foliage.* The degree of heat in which the plant was kept, according to the same author, varied the quantity of matter perspired; this being greater, in proportion to the greater heat of the surrounding atmosphere. The degree of light has likewise considerable influence in this respect: for *Mr. Philip Miller's* experiments prove, that plants uniformly perspire most in the forenoon, though the temperature of the air, in which they are placed, should be unvaried. *Mr. Guettard* likewise informs us, that a plant, exposed to the rays of the sun, has its perspiration increased to a much greater degree, than if it had been exposed to the same heat, under the shade. Finally, the perspiration of vegetables is increased in proportion as the atmosphere is dry, or in other words, diminished in proportion as the atmosphere is humid.

The more vigorous and healthy the plant, the more copious the perspiration; this function, like the rest, depending much on the vital energy. Excessive perspiration seems to hurt,

* Statical Essays, vol. I, p. 29.

and even sometimes to destroy vegetables; defective perspiration is equally injurious. It is also found, that this function is performed chiefly, if not altogether, by the leaves and young shoots. That it may be properly carried on, all leaves are deciduous; in those trees, called ever-greens, there being a constant succession of leaves, to prevent the organ of perspiration from becoming rigid.

Dr. Hales first observed, that a quantity of moisture is absorbed by plants when exposed to a humid atmosphere. This absorption, as well as the perspiration, is performed by the leaves; but in what manner has not yet been ascertained. Experiments made by *M. Guettard** shew, that perspiration is more considerable from the upper, than from the under, surface of leaves, and those of the same author, of *Dubamel*,† and *Bonnet*,‡ demonstrate, that absorption, on the contrary, is much greater at the inferior surface than at the superior. To prove this, the superior surface of one leaf, and the inferior surface of another, were covered with varnish, and the consequence was, that the former, in a given time, suffered little diminution of weight, but the latter became much lighter. Again, similar leaves

* *Memoires de l'Acad. des Sciences*, 1749.

† *Phys. des Arbres*, Tom. I. p. 158.

‡ *Traité des feuilles*, Mem. I.

were laid upon a surface of water, and it followed, that those which had their superior surface inverted gained little weight, and for the most part died in a few days; while such as had their inferior surface applied to the water became much heavier, and flourished many months. These facts make it evident, that perspiration, and absorption, are not performed by the same vessels, but that each has its peculiar organs.

It has been commonly supposed, that perspiration takes place, chiefly, when the air is warm; and absorption, on the other hand, when it is cold and moist. But unless the vessels, peculiar to absorption, which are placed in the under surface of the leaves, were kept constantly in action, they would necessarily collapse or decay. All absorbing organs have a peculiar structure, and an action depending on life: that such an organization is present in the leaves of plants, it is reasonable to conclude, because dried leaves do not absorb. The same reasoning is applicable to the absorption performed by the roots: for when a small portion of the root of a hyacinth, growing in water, is cut off, the whole root dies, and new roots are shot out, having their extremities peculiarly adapted to the absorption of nourishment;

The noxious matter, carried off by perspiration, requires large dilution to prevent its hurting the delicate structure of the leaves, and in
this

this state accordingly it is thrown out on their surface. Here the noxious part is excreted, but part of the diluting fluid is reabsorbed, to serve the purpose of secretion, which could not be performed, unless the common juice, or sap, were previously prepared. In the same manner, in the animal body, the saline and putrid matter, carried off by the urine, must be liberally diluted, to prevent it from injuring the tender structure of the kidneys; yet, when it is safely lodged in the bladder, a part is reabsorbed, and the grosser excrementitious matter is alone thrown out. Something of the same kind happens in the perspiration of animals. They certainly take in something useful from the surface of their bodies, and this is probably performed by vessels opening outwards, different from the common exhalents. The great quantity of water, absorbed during the use of the pediluvium, and that singular symptom in diabetes, of the patient's voiding a much greater quantity of urine, than there is liquor taken in by the mouth, seem to confirm this assertion.

Neither in plants, nor in animals, can we measure the exact quantity perspired or absorbed, we can only ascertain the excess of the one over the other. For example, if a heliotropium, or sun-flower, in one day lose twenty ounces of its weight, in another lose nothing, and in a third gain in weight ten ounces, it is only thence to be

be concluded, that sometimes the quantity perspired exceeds, sometimes it equals, and sometimes it is less than, the quantity absorbed.

Plants are possessed of a power of forming their different parts, and this is done by secretion. We may conjecture what the agents are which produce this effect, but in respect to the manner of their operation, we are entirely in the dark. In animals, where the vital power is strong, this is the principal agent in producing the new arrangement of parts, which is made in every secretion; but in plants, where this power is weaker, it would be unequal to perform the function, if it were not assisted by absorption and fermentation. Wherever any firm matter is to be secreted, the vessels have a convoluted course, to allow the juice to be fermented, and the thinner parts to be absorbed. In this manner, the stones and kernels of fruits are supplied with nourishment by fibres, which are much convoluted. The proper juice seems to be formed only when the sap has ascended towards the leaves, and is descending to the roots. The wood also is formed during the descent of the sap; for when a ligature is made round the stem of a tree, the wood above the ligature becomes much thicker, while that below, remains of its former size.

The pabula, from which vegetables receive the matter of secretion, are contained in the
surround-

surrounding elements. They are chiefly nourished by the water they draw from the soil; but somewhat they likewise derive from the light of the sun, on which their sensible qualities principally depend. On this subject I have likewise made some experiments, but not with that degree of exactness, which should enable me to lay them before the public.

Some botanists have conceived, that plants, as well as animals, have a regular circulation of their fluids. Others think this very improbable. On both sides, recourse has been had to experiments; and from these, conclusions perfectly opposite have been deduced. When a ligature has been fixed round a tree, in such a manner, that no juice could be transmitted through the bark, the tree has been found to thicken above the ligature; but below it, to continue of the same circumference. Hence some have concluded, that the sap ascends through the wood, and descends through the bark. Those who are of a contrary opinion have found, that, in certain cases, the juice ascends through the bark only: for when a portion of the wood has been cut out, and the bark exactly replaced, the growth of the tree has been found to go on unchanged: hence it is said, that the juice is transmitted equally through all parts of vegetables. The experiments adduced on each side of the question
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are just, but the reasonings on these, by each party, seem equally inconclusive. The analogy of animal nature appears to favour the opinion, that the juice rises through the wood only, and descends only through the bark; but this analogy is not complete throughout. The arteries are not placed in the internal parts alone, nor the veins in the external, but they accompany each other through every part of their distribution. In vegetables, the sap rises *from* the roots, but the proper juice descends *towards* them; in the descent of the juice, the wood acquires its growth, and absorption is a constant action of the leaves. These observations render it probable, that there is a circulation of the juices; and if there be, the vessels which perform it, we may reasonably believe, accompany each other through every part of their course.

On the whole we may conclude, that the formation and growth of the parts of plants, depend, chiefly, on the vital energy, which is not however exerted, except on the application of stimuli.* We admire the marks of wisdom and design, which appear in the creation and preservation of vegetables, but we have no reason to believe

* Dr. Bell from several experiments to which he has alluded, was of opinion, that many of the manures produce their effects by acting as *stimuli* on the moving fibre of vegetables. J. C.

that

that they are possessed of any intelligent power, which presides over and directs their peculiar functions.

Both plants and animals are, from their construction, much under the influence of stimuli, and all organized beings are regulated more by general, than particular, laws.

The principle of life seems universally diffused through nature, but bestowed on different beings in different degrees. To animals is given the largest share; but throughout the whole animal kingdom, one species descends below another in the perfection of its mental powers, as well as of its organic sensations. And this progression is so very gradual, that the most perfect, of an inferior species, approaches very near to the most imperfect, of that which is above it. The chain is continued between vegetables and animals. Both have the power of propagating their species, and their modes of procreation are similar. In the lower classes of animals, the powers of sense and motion are very indistinct. The coral and the water polypus adhere to rocks, as plants to the earth; and, like these, die on being severed from the place where they grew. There are likewise plants, which in many things resemble animals. The Burrhum Chundalli, lately brought from the *East Indies*, possesses a living principle, which discovers itself in the spontaneous, and almost constant motion of its

leaves. The *Sensitiva Mimosa*, and *Muscipula Dionæa*, shew wonderful activity on the slightest impressions, and take the flies and other insects prisoners, by the contraction of their leaves. That these plants *live*, will be granted; but I suspect, that they likewise *feel*. I doubt whether we are right, in confining the capacity of pleasure and pain to the animal kingdom. This I may affirm, that some circumstances, common to the generation of plants and animals, and many similarities in their functions and structure, would lead us to the opinion, that sensation likewise is bestowed on both. † It is vain to attempt to establish absolute rules, by which plants may be distinguished from animals, in every case whatsoever. There are animals, which grow to a spot, and, like plants, are nourished by the pores of the skin. And there are plants, which surpass some animals in vital power, and, perhaps, in sensation.

Wherever the principle of life exists, there is a peculiar organization; and as much mechanism is necessary to the structure of a vegetable, as of a human being. This view of the life of vegetables raises botany to the rank of philosophy:

† The excellent professor of botany in *Edinburgh*, Dr. Hope, in his course of lectures, used to speak of Dr. Bell with the highest esteem: but did not approve of the idea here thrown out, that plants possess feeling, or perception. J. C.

it adds fresh beauty to the parterre, and gives new dignity to the forest.

It only remains, that I excuse myself for writing on a botanical subject, when I am a candidate for medical honours. A few words will suffice. Such is the analogy between vegetables and animals, that the knowledge of the nature of the one illustrates that of the other: and as vegetables, in every part of the world, form a great part of our food, as well as of our medicines, it is highly important for every physician to be well acquainted with their nature.

Some OBSERVATIONS on the PHÆNOMENA, which take PLACE between OIL and WATER, in a LETTER to THOMAS PERCIVAL, M.D. F.R.S. and S.A. &c. By MARTIN WALL, M.D. Prælector of Chemistry in the University of Oxford. Read Nov. 17, 1784.

DEAR SIR,

THE action of bodies on each other, the principles upon which that action depends, and the causes, which under certain circumstances diminish, impede, or prevent it, have

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deservedly

deservedly occupied no small share of the attention of philosophers ; because on the knowledge of these principles, depend, not merely a curious science, but very many of the necessary arts of life. In the earliest periods of philosophy, little progress was made in this investigation. Some crude conjectures were advanced concerning peculiar emanations, &c. which, having no foundation in experiment, were as quickly rejected as they had been formed. The patrons of the corpuscular philosophy imputed the influence of bodies on each other, or the defect of such influence, to the peculiar forms of their original particles ; and the mechanic sect superadded to this system the doctrine of attraction. The theory which depends upon the form of the constituent particles of bodies, is very weak and unsatisfactory, and, if it has not been absolutely confuted by experiments, has certainly received no confirmation from them. But the grand principle of attraction, has, by the clearest evidence of conclusive facts, received the most ample confirmation, its laws have been explained, and the universal extent of its operation has been so fully demonstrated, that *Bergman* was perfectly justified in speaking of it, as the principal agent in every operation, grand or minute, in the system of the world, “ cui omnia in globo nostro obedire videntur.”

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The action, however, of this great agent is not simple and uniform: it admits of great variation, and operates by different laws, as we see in the different phænomena of gravitation, of cohesion, of electricity, of magnetism, and of chemical affinity. Thus, in our electrical and magnetical experiments, we have frequent occasion to observe, that the same bodies which are attracted by one are repelled by a third, and *inter se*, as the circumstances of the experiment are varied. Perhaps, something of the same kind may limit or impede the attraction of gravitation and cohesion, in particular cases. Hence philosophers have supposed another principle of nature, opposite to that of attraction, which they have denominated *repulsion*, and have imagined the influence of this principle to begin, where that of attraction ends. The observations deduced from the phænomena above alluded to, have been transferred also to chemistry; and because certain bodies shew no disposition to form a chemical union, they have been said to possess a *repulsive* faculty with respect to each other. To say, that a principle of repulsion has no existence in nature, would be too presumptuous: but I am inclined to believe, that the species of attraction, which constitutes chemical affinity, is not counteracted by any principle of repulsion in those cases, where no affinity appears to take place; and that the apparent

repulsion depends upon a perfectly different cause. To pursue this doctrine through all those instances of chemical subjects, which shew no disposition to unite, would be almost endless; but that I may give it a little illustration, permit me to draw your attention to one example.

One of the most common examples adduced of this repulsion, is, the immiscibility of oil with water, which cannot be effected without some intermedium. But what is here called repulsion, is perhaps, only a case of that kind which is called elective attraction (if I may be allowed to adopt that expression); that is, that the particles of water attract those of water, and the particles of oil those of oil, more strongly than oil attracts water; and, therefore, when these are mixed or brought into contact, no new or more powerful attraction taking place, both ingredients continue distinct and disunited: and it is upon the same account, that when one of these fluids is *inveloped* in the other, it is disposed to form itself into one or more spherules from the strong attraction of its particles *inter se*.

The principle thus laid down will receive illustration from, and at the same time will assist to explain, some phænomena resulting from the immiscibility of oil and water, which, though well known, have not been much regarded in a philosophical point of view. The facts, to which I particularly allude, are, the effect of
oil

oil and oily substances in preventing the crystallization of salts, and in smoothing the waters of the sea, &c. when agitated by winds.

The general process for making common salt at *Droitwich*, we are told, by Dr. *Nasb* in his History of Worcester-shire, is, first to put a little common water into the pan to keep the brine from burning to the bottom: the pan is then filled with brine, and a piece of resin about the size of a pea thrown in to make it granulate fine. I doubted, he adds, the resin's having any such power, but am assured by Mr. Romney, a principal and observant proprietor, that the more resin they use, the finer will be the grain of the salt; and if a lump of the size of two walnuts were put into the pan, the grain would be so fine as not to subside at all. (*Nasb's Hist. of Worcester-shire*, vol. I. p. 300.) The same effect, which is here ascribed to resin, may be obtained by the use of butter, tallow, and any other oily matter, which will liquefy by the heat used in boiling the brine, and, when so liquefied, is incapable of mixing with the water. In consequence of this, it forms a thin film upon the surface, greater in proportion to the quantity used.

To the perfect crystallization of salts, it is required, that the water which holds them in solution be slowly evaporated, and that the surface be extensive, quite open, and exposed to the

free access of air, because air is requisite to the formation, and, perhaps, as well as water makes a constituent part of every perfect crystal. If the surface of the water have not a free communication with the air, and the boiling be carried on rapidly, the salt falls down in small granules, and no crystals are formed. This appears to me to be the effect of the thin oily film in the process above described, which is explicable upon the principles formerly advanced.

Of the effect of oil in smoothing troubled waters, so full an account is given by Dr. *Franklin*, in the Philosophical Transactions for 1775, that it is not necessary to be particular as to the matter of fact, which is now generally known. I think this fact also is easily explicable upon the principles, which I have laid down, viz. that the particles of oil have a stronger attraction for each other (or *inter se*,) than they have for water, and probably, than they have for air. Air, we know, has a considerable attraction to water, so that the one is seldom free from the other, and, when they are brought into contact, they seem to unite and adhere by the double force of chemical affinity and mechanical cohesion. Therefore, when a considerable body of air is forcibly impelled, as in a storm, upon the surface of water, it in a manner *lays hold* of the water, carrying or forcing
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it along with it in its course, until the water, reacting by its gravity, returns forcibly to repair its level; and by this repeated impulse and reaction, the surface of the water undergoes that violent agitation, which constitutes a storm. But if oil be thrown on the surface of the water, it spreads itself over it to a considerable extent, and the wind is prevented from *laying hold* of the water, but glides ineffectually over it without causing any tumult or agitation.

In some parts of this illustration, I shall be found to agree with Dr. *Franklin*, but to differ materially in this, that he ascribes the spreading of the oil on the water to a *repulsive* force, which, with the utmost diffidence and deference to his eminent abilities, I am disposed not to admit. I think the principle, which I have laid down, sufficiently adequate to the explanation of the phænomenon, that the particles of oil have a very strong attraction for each other, and have none at all for water, and probably not for air. The very circumstance of the oil's spreading over the whole surface of the water in one uninterrupted film, seems to favour my hypothesis; for, if the particles of oil had a repulsion to water, and at the same time a strong attraction *inter se*, they would probably not spread equally over the surface, but form into distinct globules, and immediately upon touching the water, would recede from it to the nearest part of the
margin

margin or shore. But, according to my supposition, when any quantity of oil is poured upon water, being lighter than that water, it will necessarily swim upon it; and by the common laws of hydrostatics, it will immediately tend to form an exact horizontal level: in doing this, it will spread upon the surface of the water, till it forms a film almost inconceivably thin, and perfectly unbroken, on account solely of the strong attraction of the particles of oil to each other.

I will close these observations with a few remarks on the singular fact, to which I have just now alluded.

The world is disposed to call this a discovery of *Dr. Franklin*; but in that they are much mistaken. He himself does not pretend to claim the discovery of this fact; nay, he produces many proofs, that it was well known and applied long ago. It requires, however, very frequently the name of an ingenious man to persuade us to take notice of a very common phænomenon; for this singular operation of oil, though it excited so much attention, as a novelty, when introduced by *Dr. Franklin*, was long ago remarked by naturalists much less informed than those of modern times. Of this I shall mention a few instances, in addition to those alluded to by *Dr. Franklin*. *Pliny* says of the sea, “*Anne Oleo tranquillari, & ob id urinantes ore spargere: quoniam*

quoniam mitiget naturam asperam, lucemque deportet." *Plutarch* proposes as one of his natural questions, Δια τι της θαλαττης ελαιω καταρραινομενης γινεται καθαφανεια και γαληνη; "Why does the sea, when sprinkled with oil, become more serene and transparent?"

We find also, that the knowledge of this effect of oil was common in the earliest ages after the revival of learning, from a curious passage in the *Naufragium* of *Erasmus*; "Non nulli," says he, speaking of the various efforts of the sailors in the storm, "procumbentes in fabulas adorabant mare, quicquid erat olei effundentes in undas." A note in the Elzevir edition of *Erasmus*' *Colloquies*, thus illustrates the passage; "Ea natura est olei, ut lucem afferat ac tranquillet omnia, etiam mare, quo non aliud elementum implacabilius."

Nor has this property of oil been considered merely as a matter of speculation and amusement to philosophers: it has been applied, from time immemorial, by the natives of various and distant countries, who could not have learned it from each other, to the most important use in procuring provisions; by the fishermen on the coast of *Provence*, to enable them more readily to see the muscles and other shell fish under the sea; by the same order of men in the *Tagus*, near *Lisbon*; and by the inhabitants of the *Hebrides*,
even

even the most remote of the western isles, *St. Kilda*.

About fifteen years before the publication of Dr. Franklin's Memoirs, the following paragraph, perhaps copied from some London Newspaper, was inserted in the Annual Register. "It has been remarked, it is said, that the oil spilt into the river to prevent the spreading of the late dreadful fire in Thames street, visibly quieted the waves thereof. This efficacy of oil, in smoothing the surface of water, seems to have been long known. By an ancient law, when goods were to be thrown overboard to lighten the ship in stormy weather, if there happened to be any oil on board, and it could be come at, it was to go first; and the Ragusians at this day, when they go a fish-spearing, throw oil upon the water with a sprinkling brush, and thereby obtain a clear prospect of the bottom. The openings thus formed by the drops they expressly call *windows*."

By all these observations, it will appear, that Dr. Franklin cannot be called the discoverer of this fact: but still the philosophical world is greatly indebted to the ardour and zeal, with which he prosecuted his inquiry and experiments, which enabled him to give so ingenious an illustration of the phænomenon.

FACTS and QUERIES *relative to* ATTRACTION and
REPULSION. *By* THOMAS PERCIVAL, M.D. &c.

To the LITERARY and PHILOSOPHICAL SOCIETY.

MANCHESTER, DEC. 5, 1784.

I COMMUNICATED to you, a few weeks ago, some curious and valuable observations, on the phenomena which take place between oil and water, transmitted to me by my learned and very ingenious friend Dr. Wall, of Oxford. My engagements deprived me of the pleasure and instruction, of attending their discussion in the society: And, solicitous to recover what I have lost, I trust you will indulge me with permission, to recall your attention to the subject, by the recital of a few miscellaneous facts and enquiries, which the perusal of that paper suggested to my mind.

I. If a glass tumbler, containing equal parts of water and of oil, in such quantity as to occupy two thirds of it, be suspended by a cord, and swung backwards and forwards, the oil will remain perfectly smooth and undisturbed, whilst the water, below, is in violent commotion. But if the oil be poured out, and its place supplied
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with water, the fluid will remain perfectly tranquil, throughout the whole vessel, although the same motion be given to it as before. I have frequently repeated this experiment, and have sometimes varied it, by substituting rectified spirit of wine, in the place of water. The oil then being the heavier fluid, becomes agitated, whilst the spirit remains at rest. Dr. Franklin, who first noticed this singular phenomenon, informs us, that he shewed it to a number of ingenious persons. "Those," says he, "who are but slightly acquainted with the principles of hydrostatics, &c. are apt to fancy, immediately, that they understand it, and readily attempt to explain it: But their explanations have been different, and, to me, not very intelligible. Others more deeply skilled in those principles, seem to wonder at it, and promise to consider it. And I think it is worth considering. For a new appearance, if it cannot be explained by our old principles, may afford us new ones, of use perhaps in explaining some other obscure parts of natural knowledge."* It is with diffidence, I offer as a conjecture, that the fact, in question, may arise from a *repulsive power*, subsisting between the particles of oil and water, and depending possibly on the vibrations of that subtle æther,

* See Dr. Franklin's Letters and Papers on philosophical subjects, p. 438.

which

which Sir Isaac Newton supposes to pervade all bodies. For, when this æther is excited into motion, by percussion or agitation, its elastic force is augmented, because it becomes denser in the pulses of its vibrations, than in a quiescent state.* But in proposing this hypothesis, I may perhaps be chargeable with the paradoxical opinion of a celebrated French philosopher, M. Fontenelle, who asserts, that if there be more than one way of accounting for any appearances in nature, there is a general presumption, that they proceed from causes, which are least obvious and familiar. I shall not, therefore, at present, enlarge upon this point, as it would anticipate what may be better urged, in our subsequent conversation. But the facts, above recited, furnish a presumption, that the effect of oily substances, on the crystallization of salt, is, in part, owing to a mechanical cause. At Droitwich, it is the practice, as appears by Dr. Wall's quotation from the history of Worcestershire, to throw, into the brine pan, a piece of resin, about the size of a pea, to produce a finer granulation. The more resin they use, the smaller will be the grain of the salt; and if a lump, of the size of two walnuts, were put into the pan, the particles of salt would be so minute as not to be capable

* On the properties of Æther, consult Dr. Bryan Robinson's *Works*, *passim*.

of subsiding. Resin, butter, or tallow, when liquefied by the heat of the boiling brine, float upon its surface, and will remain perfectly smooth and undisturbed, whilst the water, beneath, may be put into strong agitation, by the action of the fire. Such agitation must break down the crystals of salt, as they shoot; and consequently, only small granules will be produced.

II. Every one has experienced the suffocating effects of air, loaded with the effluvia of burnt grease, or the snuff of a lamp. When such fumes are inspired, there is the sensation of a conflict in the lungs, which essentially differs from what is felt, on breathing either fixed or inflammable air. And is not the most easy solution of it, to suppose, that the air quits the oily, to unite with the watery vapours, which are brought into contiguity, by this action of the animal œconomy; and that a strong repulsion succeeds? “For, as, in algebra, where
 “ affirmative quantities vanish and cease, where
 “ negative ones begin, so, in mechanics, where
 “ attraction ceases, there a repulsive power ought
 “ to succeed,” according to the doctrine of Sir Isaac Newton. It is, also, an axiom, laid down by this great philosopher, that “to the same
 “ natural effects, we must always assign, as
 “ far as possible, the same causes.” I shall therefore proceed to illustrate this subject, by other more decisive examples of *repulsion*; after
 premising

premising a few observations on that species of *attraction*, which appears to be the converse of it.

III. That the particles of homogeneous bodies have an affinity to, and consequently attract each other, is consonant both to analogy and observation. Fluids manifest this property, by their disposition to assume a globular figure, and by the rushing together of these globules, when brought within their reciprocal sphere of activity. A similar attraction subsists between heterogeneous substances, which is distinct from that of *cohesion*, as it partakes of an *elective* nature, and yet cannot be deemed *chemical*, because no combination is produced by it, so intimate, as to manifest any change of properties. This may be illustrated by the increase of power, in the suspension of weights, which a hair acquires, by being moistened with different liquids. For such additional strength is not proportioned, precisely, to the tenacity of the liquid employed; and probably subsists in a duplicate ratio, compounded of the affinity which the parts of the liquid bear to each other, and to the minutest fibres of the hair. The particles of water attract one another more strongly, than they attract polished wood or stone; whilst, on the contrary, they are less forcibly attracted by each other than by glass. This is evinced by the common experiment with capillary tubes. For the water, which ascends, must have quitted the con-

tact of the water left behind, contrary to their mutual affinity, as well as to the law of gravitation. The particles of quicksilver, like water, are attracted by glass. For if a small globule of this metal be laid upon unsullied paper, and touched with a piece of clean polished glass, the quicksilver will adhere to the latter, in preference to the former, and may be drawn away with it. But the relation of mercury to glass is of inferior force, to that which subsists between its own particles. This will appear by dipping a bent tube, open at both ends, into a vessel, filled with quicksilver, which will enter into the tube, but stand within it, below the surface of the mercury, at a depth, proportionate to the diameter of the tube. * It is unnecessary to adduce further instances of this attraction; and I shall endeavour to shew, that where it does not subsist, a repulsive power apparently takes place. This, according to the laws of optics, has been deduced from the globules of rain, which lie on the leaves of colewort, whose lustre and mobility are so striking to the eye. For, on a close inspection of them, it is found, that the lustre is produced by a copious reflection of light, from their flattened inferior parts. It has also been further observed, that when a drop

* Consult Dr. Jurin's Experiments, Philosophical Transactions, No. 363; also Cotes's Hydrostatical Lectures, p. 231.

rolls along a leaf, which has been wetted, its brightness disappears, and the green leaf, before hardly discernible, is now seen clearly through it. From these facts it is inferred, that the globe does not touch the plant; but that it is suspended at some distance, in the air, by the force of a repulsive power; because there could not be any copious reflection of white light, from its under surface, unless a real interval subsisted between that surface and the plant.* This hypothesis accounts for the volubility of the drop, and for its leaving no trace of moisture, where it rolls. From the like reasoning it hath been concluded, that when a polished needle is made to lie on water, it is not in contact with that fluid, but forms, by repulsion, a bed, whose concavity is much larger than its own bulk. Hence it is readily conceived, how the needle swims upon a liquid, lighter than itself; since the quantity of water, displaced by it, may be equal to its weight. Can it be philosophical, to attribute such a phenomenon to the tenacity of water, or to the attraction subsisting between its particles?

IV. The attractions and repulsions between those exhalations that are termed dew, and certain substances exposed to them, are still more remarkable, than the facts which have been

* See Newton's Optics, Query 29. Also Physical and Literary Essays, vol. II. p. 25.

already recited. M. Musschenbroek placed different bodies, for the reception of these vapours, on the terrace of the observatory at Utrecht, and found that some caught them abundantly, others only in a small quantity, but that a third sort repelled them altogether.* M. du Fay, of the French Academy, repeated these experiments, and fully proved that, whilst the dew fell copiously into vessels of glass, not the least moisture was apparent in vessels of polished metal, contiguous to them. To be assured whether the difference was always the same, in all circumstances, between vitrified substances and metals, he set a China saucer in the middle of a silver plate, and, on one side, adjoining to it, put a silver vessel, very like the saucer, upon a China plate. The former, viz. the China saucer, was covered with dew, although the plate, which spread four inches around it, had not a single drop. The China plate, also, received the dew, whilst the silver vessel, that was in the middle, remained as dry, as when it was first exposed.

The same ingenious philosopher endeavoured to ascertain, whether a China saucer, set upon a plate of metal, in the manner above described, did not receive more dew than it would have done, if exposed quite alone. To accomplish this design, he took two watch crystals, of equal

* Introd. ad Philos. Nat. vol. II. p. 990.

dimensions, and placed the one upon a plate of silver, the other upon a plate of China, each with its concavity uppermost. That which was upon the silver plate, he surrounded with a ferrel, of the same metal, well polished, that no watery particles might attach themselves to the convex surface of the glass. Thus circumstanced, he exposed the crystals, several days successively, in a proper situation, and always found five or six times more dew in that, which was on the China plate, than in the other placed on silver: And this may be regarded as a presumptive proof, that the moisture repelled from the metal, was attracted by the China. That there subsisted such a repulsion, is confirmed by the following observation of M. du Fay, with regard to the crystal on the silver plate. He informs us, that the small quantity of dew on the inside, was only near the center, in minute drops; and that, round the border, there was a space of five or six lines, perfectly dry, towards which the drops regularly decreased, in magnitude; as if the silver ferrel had *driven away* the dew from that part of the glass, which was contiguous to it. These experiments were repeated thirty times, with invariable success.* And Dr. Watson, now Bishop of Landaff, has lately confirmed them, by some very curious trials, of a similar kind, made to determine the quantity of vapours

* Vid. Hist. de l'Acad. des Scienc. 1749.

which ascend, in a given space, from the surface of the earth. "By means of a little bees wax," says he, "I fastened a half-crown very near, but not quite contiguous to the side of the glass, and setting the glass, with its mouth downwards, on the glass, it presently became covered with vapour, except that part of it, which was near to the half-crown. Not only the half-crown itself, was free from vapour, but it had hindered any from settling on the glass, which was near it, for there was a little ring of glass surrounding the half-crown, to the distance of a quarter of an inch, which was quite dry, as well as that part of the glass, which was immediately under the half-crown; it seemed as if the silver had repelled the water to that distance. A large red wafer had the same effect as the half-crown; it was neither wetted itself, nor was the ring of glass, contiguous to it, wetted. A circle of white paper produced the same effect, so did several other substances, which it would be tedious to enumerate." *

Do not the instances of repulsion, here adduced, with various others, which may perhaps be recollected and noticed by the Gentlemen present, warrant us to conclude, that this principle is a powerful agent, in the operations of nature? To this cause, the air we breathe owes, pro-

bably, its existence and elasticity; the light, which illuminates our globe, its rapid motions and diversified inflections; and fire, its genial, expansile, and animating energy. Is it, therefore, consistent with analogy, to exclude repulsion from that branch of physics, which chemistry comprehends? The subject certainly merits further investigation: And I shall state, to my friend Dr. Wall, the facts and queries, which I have now laid before this Society; that he may communicate to us, such limitations or confirmations of his doctrine, as an attentive review of it may suggest, to his ingenuous and philosophic mind.

EXTRACTS of TWO LETTERS from Dr. WALL of OXFORD, to Dr. PERCIVAL, in Reply to the foregoing QUERIES concerning ATTRACTION and REPULSION; communicated to the LITERARY and PHILOSOPHICAL SOCIETY. Read January 12, 1785.

DEAR SIR,

IT gives me great pleasure to think that my paper on oil, &c. was so far approved, as to be thought worthy of a place in your Memoirs. I am by no means positive, that my hypothesis

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will

will absolutely stand the test of examination, so far as to prove, that there is no principle of repulsion in chemistry: but I think still, notwithstanding your very ingenious observations, that, in most cases, APPARENT REPULSION may be resolved into ELECTIVE ATTRACTION. The experiment, which you first adduce, made with a mixture of oil and water agitated in a glass vessel, if I understand it right, appears to me not to affect the point in question. I think that the commotion, which the water undergoes while the oil remains tranquil, depends upon the different specific gravity of the two fluids (whereby they receive the force of the impulse in unequal proportions) and upon the disposition of the oil, from its superior levity, to preserve its place, upon the top of the water, whatever agitation the water beneath may be subjected to. In the boiling of brine, I admit that the agitation of the water must have a considerable effect in breaking down the crystals of salts, and thus preventing their regular and complete formation: but this cannot be all that takes place, when an oily substance is put into the brine; because, if it were, the same effect would result from boiling the brine only without the addition of any oily or resinous matter.

Forgive me, in the second place, if I should not agree with you in explaining the conflict, which is felt in the lungs, upon the inspiration of the fumes of burnt oil, in the same manner

as you do. I think your theory too subtle. What is the primary action of atmospheric air, received into the lungs; and what appears to be the operation it performs there, before it is respired? Do not the late observations of innumerable chemists shew, that it is in part converted into fixed air in that process, and in part phlogisticated, by carrying off the phlogiston, separated from the blood in the circulation, and discharged by the lungs? The more perfectly the air inspired is dephlogisticated, it answers the demand of nature more entirely; but when it is either largely mixed with fixed air, or loaded with phlogistic particles, such as the empyreumatic vapours from burnt oil, it is rendered unfit for these important purposes, and, instead of carrying off noxious matters, it conveys into the lungs a new cause of offence; and thus produces a sense of conflict and uneasiness in a two-fold manner; by not carrying off the load from which the constitution is usually freed by the process of respiration; and by superadding a *stimulus ab extra*.

I cannot admit the application of the laws of mechanical attraction, much less the properties of algebraic quantities, to the phænomena of chemistry. It was well observed by the late excellent Dr. Lewis, of Kingston, in his Philosophical Commerce of Arts, “ that it is of great importance, that these two orders or forms of
“ attraction

“ attraction (the mechanical and the chemical)
 “ should be properly distinguished and separated
 “ from each other, as many errors have arisen,
 “ from applying to one, such laws only as obtain
 “ in the other.”

Your illustration of repulsion, from the beautiful appearance of the drops of water on colewort leaves, seems, at first view, to present a most forcible objection to my system; and yet perhaps upon more mature consideration, that fact may be assumed as a confirmation of it. For water, from the strong attraction of its particles to each other, especially when the quantity is inconsiderable, and is allowed to fall upon an inclined surface, does not adhere to that surface, but forms itself into globules, and runs off, till by the breaking of some of the drops, or the accidental *remora* of others, that surface becomes wetted, and then the drops no longer exhibit the property above-mentioned. And this is sometimes remarkable, even when the water falls upon substances, which in other circumstances are much disposed to imbibe it, and to unite with it; as when water is let fall from a height on a surface covered with dust, with flour, &c. And a similar state may obtain upon colewort, and some other large leaves, which are smooth, and are liable, after a dry season, to become covered with the fine dust that floats in the air; or possibly, there exsudes on the surface of such
 leaves

leaves a resinous farina, or fine oily dew, by which the drops of water falling upon them will be, for some time, prevented from coming into immediate contact with the leaves; but will roll off, formed into spherules by the *intrinsic* attraction of their particles, as quicksilver rolls off from wood, &c.

The phænomena of quicksilver (thus casually mentioned) will indeed greatly illustrate this subject; for that fluid is very remarkable for the strong attraction of its particles *inter se*. You may argue, that mercury, falling upon wood or marble, forms itself into globules upon account of its repulsion from those substances; but if it be allowed to run upon other bodies, to which it has a strong affinity, it displays the same property in various degrees, according as that affinity is more or less strong, more or less powerful to overcome the attraction of its particles *inter se*, and to counteract their disposition to form into globules. Thus mercury, poured upon gold and silver, breaks at first into globules; but these are almost immediately attracted by those metals, lose their mobility, become flat, and, if allowed to continue, amalgamate with the gold or silver: but, poured upon tin or copper, the mercury separates into globules in the same manner, as if it was poured on wood or marble. These globules continue a long time perfect, but at last unite with the tin or copper; because the
attraction

attraction of these two metals to mercury is much weaker, than that of the perfect metals, and does not, for some time, overcome the attraction of the mercurial particles *inter se*; therefore the globe preserves its form longer. As I believe it will be admitted by every body, that no repulsive power operates between mercury and either of the four metals, which I have mentioned; I think it will also be admitted, that the phænomena, to which I have alluded concerning them, may be satisfactorily explained upon the principles of my hypothesis. And if this hypothesis applies so well in these instances, it is allowable to extend it to other similar facts, concerning the powerful or weak action of mercury on other metals, and even to transfer it to explain the appearances, which other fluids present in parallel circumstances. From this example then I am induced to conclude, that the attraction of the particles of any fluid *inter se* is the cause, why that fluid forms itself into globules, when it is in contact with another substance of any kind, to which that fluid has no chemical affinity or attraction, and thus may give that appearance of abhorrence or repulsion, by which chemists have hitherto been persuaded to adopt the idea of a repulsive principle, opposed to that of attraction. Remember, that I am here speaking solely of chemical phænomena. I do not pretend to touch upon mechanical, magnetical,

magnetical, or electrical attraction or repulsion. These, especially with respect to magnetism and electricity, are perfectly established. Whether there is any mechanical repulsion, independent of these, or the elective attraction, of which I have said so much, may perhaps be disputed.

By this reserve, I think, I obviate your objection to my theory, drawn from Mr. *Melville's*, or *Musschenbroek's* experiment of the needle. Probably, this phænomenon is connected with other principles, than those which chemistry will supply. The suspension of the needle depends upon its exact level position on the surface of the water, and upon the great extent of the surface, when compared with the bulk of the needle and the quantity of water, which it must displace when it sinks. Only the lower side of the needle *touches* the water, and no part of the upper side is wetted at all; for if any part of the upper side be so wetted that either end is depressed, the gravity of the different parts of the needle not acting separately, but in combination, the whole overcomes the resistance of the water, and the needle sinks. In the same manner, many substances, specifically heavier than water, may be made to float upon water by considerably extending the surface. Instances of this fact are so numerous, that they need not be mentioned; and that this is really the case in the experiment under consideration, is obvious from
this

this circumstance, that the experiment succeeds best with the finest needles, and if we repeat it successively with different needles; of different sizes, from the smallest to the largest; we shall find the experiment more and more difficult; and at last impracticable; because, although in the smaller needles the bulk of the whole bears comparatively a very small proportion to the extent of their surface; in the larger needles this is not the case, and, therefore, the common law of specific gravity takes place, and the needle sinks in the water. I have paid a good deal of attention to this experiment, both with the naked eye, and with a magnifier, and cannot say that I am satisfied, that Mr. *Melville* is accurate in asserting, that the needle is not in contact with the water. It forms indeed, as he says, a bed for itself, and depresses the water, but, if we observe minutely, we see that the water touches the lower surface or sides of the needle in many minute points. Why the water does not come into more general contact with the needle, depends probably upon the same cause that disposes water to form globules upon the surface of any highly polished metal, or almost any other inflammable substance: and to the explanation of this point the same principles of chemical attraction, so largely insisted upon in this and my former letter, lend their aid. Water, and all watery fluids, have little or no attraction

attraction to substances, which contain a large proportion of phlogiston. Exceptions might be brought to this position, but these might be so easily obviated, that the fact may be admitted as general. Metals particularly exemplify this point; especially if they are highly polished, when their surface is so perfectly clean, that all those properties, which depend upon the phlogiston, are most obvious and perceptible. If water be poured upon a metal in this state, it is with difficulty made to wet the surface, but runs off immediately; or if it adheres, it adheres in a discontinued and broken manner. Iron, when wrought to the high temperature of steel, peculiarly exhibits this appearance. And something of the same kind may be supposed to obtain, when a small piece of highly polished iron, such as a needle, is laid upon water. Hence the needle, though it is suspended on the surface of the water, yet does not, except perhaps in the very lowest part of it, touch the water, but in a few points.

After all, I would have it perfectly understood, that I by no means pretend to deny the facts, which seem to evince a repulsive principle; but only presume to offer my opinion, that in chemistry, these facts may be explained by the doctrine of superior elective attraction, without the necessity of introducing more principles or causes, than the facts seem to require.

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I am glad my remarks on your observations met with your approbation. If you think they will at all illustrate the subject, the Society have my full permission to do what they please with them; if they should not think they will take more room than they deserve, I shall esteem their approbation a great honour. But they will seem to stand insulated and alone, and perhaps will not be perfectly intelligible, unless they are introduced by your observations, which were the cause of them.

The more I reflect upon the subject, the more I am convinced of the power and extent of the influence of attraction in chemical phænomena. In solution, it has been admitted ever since the time of Sir Isaac Newton; but there are many other facts, which the late experiments on elastic fluids lead us to explain in the same manner.

I shall, in this letter, only have time to exemplify this position, by directing your attention to the circumstances, which take place in the CALCINATION OF METALS. The experiments of Stahl, &c. convincingly prove, that metals in calcination part with the phlogiston; and those of Mr. Lavoisier shew, that the calx of a metal, thus deprived of phlogiston, is not merely an inert earth, but that it is the base of the metal united with the ærial acid, or fixed air. It is
obvious,

obvious, therefore, that in the process, the action of the fire expels the phlogiston from the metallic earth, which then attracts the ærial acid, either floating in the air, or generated by the fire, and continues united with it, till by proper circumstances of application the phlogiston is again brought to act on the metallic calx, and to unite with it; and the ærial acid being expelled the metallic is revived. This, then, is one of those cases of elective attraction, which is varied by the degree of heat. To prove that what I have said above is just, let us examine another mode in which metals are deprived of their phlogiston, that is, by solution. A metal, perfectly dissolved in its proper acid menstruum, is held in solution, till some substance is added, which has a greater attraction to one of the ingredients, than they have to each other. Thus, a mild alkali added, attracts the acid, and the metallic earth is precipitated. It is a calx, in all circumstances the same, as that obtained by perfect calcination; and here it also indisputably contains the ærial acid. Indeed, we in a manner see it take possession of the fixed air in the process: for when the alkali is added, and attracts the acid, no effervescence ensues, though we know the alkali parts with its air, whenever it unites with an acid. It is therefore certainly absorbed by the precipitated calx, and with that, by experiment, we find it united. Again, if we add to a solution of any

metal in an acid, another metal which has a stronger attraction for that acid, we know that the former metal will be precipitated; and the latter taken up in its place: and the former will be precipitated, not in a calcined, but in a metallic state; because, in this instance, the precipitated metal attracts the phlogiston, of which the other metal is deprived by its solution. It appears therefore that the whole business of the calcination and reduction of metals depends upon the laws of single or double elective attraction, either simply in solution, or as they are affected and varied by heat. It appears too, how nearly these processes are connected with the doctrine of the elastic fluids, with which we are so lately made acquainted; for the properties of fixed air are fully established; and I think, the more recent experiments of Dr. Priestley, &c. go near to shew, that the phlogiston of metals, if not exactly the same, is certainly nearly the same, as inflammable air.

On the VOLUNTARY POWER which the MIND is able to exercise over BODILY SENSATION. By THOMAS BARNES, D.D. Read November 3, 1784.

THE mutual action of the body and the mind upon each other is felt every moment. The knowledge of the nature, effects, symptoms, and measures of these reciprocal influences, forms no inconsiderable part of the science most necessary to the physician, the moralist, and the divine. It enters deeply into every study, of which either body or mind is the professed subject. And whatever difficulties may attend our inquiries, in the way of mere theory and speculation—difficulties which arise from the narrow limits of the human faculties, and from the absurd attempt to investigate the *essences*, rather than the *operations*, of nature—yet we may acquire from EXPERIMENTS and FACTS a knowledge, clear in its evidences, certain in its principles, and important in its application.

The question which I have proposed to consider, “Whether the mind has any kind of voluntary

luntary power over bodily sensation," is not merely speculative. It must be determined by an appeal to facts; and its influence is, in a high degree, practical and interesting.

SENSATION is generally defined to be—"A perception in the mind, excited by means of the organs of sense, independently on the will." Thus, when my eye is open, external objects make an impression; nor is it in the power of my mind, if the organ is sound, to exclude the vision. In like manner, the touch, the taste, the smell, produce their correspondent feelings, which the mind passively receives, because it is not able to repel them. If this be true of pleasant, it is still more true of painful sensations. Over these, it is said, the will has no controul. Sense will be sense; and pain will be pain, notwithstanding all our endeavours to blunt the acuteness of the one, and the anguish of the other.

This sentiment, though true to a certain point, is not however so absolutely and invariably true, as to admit of no limitation. Many strong facts prove, that the mind is not so entirely the slave of sense, as to have no power at all to suspend, or, at least, to moderate its impressions. In many instances, she is able to exercise some measure of that regency, which her nature and office authorize her to maintain over her material and mortal partner.

Sensation

Sensation itself is probably different in different persons. It depends on the state both of the bodily organs, and of the percipient mind.

It is therefore varied, by age, by culture, and by every circumstance which can affect the temperament, either of the mind, or of the body. Some systems are naturally more irritable; others more firm. In some, all bodily impressions are extremely pungent; in others, comparatively languid. The same habit is probably not equally disposed, at all times, to the endurance of pain. The temper of the mind, and the state of the nerves, admit of so much inequality, that it may demand much greater fortitude to suffer calmly, at one period, than at another.

In general, whatever fixes the mind in INTENSE THOUGHT, or rouses it to STRONG PASSION, makes it less sensible to organical impression. "How often, says Mr. Locke, may a man observe in himself, that whilst his mind is intensely employed in the contemplation of some object, and curiously surveying some ideas that are there, it takes no notice of impressions of sounding bodies made on the organ of hearing? A sufficient impulse there may be upon the organ; but it not reaching the observation of the mind, there follows no perception."* Effects similar to this almost

* Essay on Hum. Und. Lib. II. Ch. 9. § 4.

every person must have experienced. For who has not, for a time, forgotten the calls of appetite, the sense of cold, or even the feelings of acuter pains, when his attention has been engaged, by an interesting story, an affecting oration, or an agreeable amusement? Of this absence of mind, and of an inattention to bodily wants arising from it, many curious instances are given in the Life of Sir Isaac Newton. Buried in profound meditation, that great philosopher, we are told, often remained for many hours together beyond the regular time of sleep, and of meals, equally insensible to the demands of food, and of rest; and sometimes ignorant whether he had eaten or not.

But these effects are still more conspicuous, when the mind is roused to STRONG EMOTION: for PASSIONS, of almost every kind, produce a momentary pause of sensation. How many instances have there been, of persons under severe fits of the gout, who, upon some sudden alarm, have entirely lost the present sense of pain, and have made exertions, which, in their crippled state, would have been thought impossible? I cannot resist the impulse of mentioning, to the honour of a British tar, the strong effects which the love of his country, and the spirit of his profession, produced upon the late gallant ADMIRAL SAUNDERS. He had been for some time laid up under the extreme debility and langour,
which

which often attend that excruciating disease. A friend, calling one day to see him, found him, to his great astonishment, standing to wash himself in his shirt sleeves, with all the marks of perfect health and agility! Upon inquiring into the cause of this sudden change, the admiral exclaimed, " I have received an order from
" government to take the command of a fleet
" against the Spaniards, and I will not come
" back again without striking a blow."—This order was in consequence of the dispute relating to the possession of Falkland's Islands, in 1771. The powerful excitation of this animating appointment gave, for some time, a new spring to the constitution of the brave veteran, and procured him a truce from the miseries of his situation. But soon after, the rumors of war dying away, the admiral sunk down again into languor and disease.

In this instance, the effect was of some continuance, because the passion called into exercise was of a lasting nature. There was a great object before the mind, which continued to stimulate its energies for a considerable time. In that most humiliating and affecting of all human calamities, the loss of reason by madness, the feelings of sense seem to be almost entirely extinguished. The scourge, and the knife appear to be equally unfelt. The sense of hunger and of cold is suspended: Providence having kindly

ordained, that where the moral influence of pain cannot be enjoyed, its anguish shall not be endured.

Violent passions, of every kind, during their continuance, produce this effect, of sheathing the pungency of sensation. Fear, and hope, joy, and sorrow, when strongly excited, equally bring on a temporary insensibility: so that a person shall receive blows or wounds, without feeling them. How plainly does this appear in children, who, in anger, or in play, will endure unmoved, what would otherwise be felt with the most exquisite keenness? In some places, the common expressions of sorrow are, to beat the head, to tear the hair, and in Otaheite to strike sharks teeth deep into their flesh, thus inflicting wounds, the marks of which appear with indelible impression.

But though all the passions have equally a benumbing power, whilst their paroxysms continue, yet the effects produced by them *afterwards* on the system, with respect to the acuteness of sensation, are widely different. Some passions depress the mind, weaken the tone of the spirits, and render them feelingly alive to every touch. Thus, fear, and sorrow, after their first violence is spent, unbrace the nerves, give acuteness to pain, and often convert indisposition into disease, and anguish into agony. Other passions, on the contrary, induce a firmness, a tension, a
vigour

vigour of soul, which enable it with greater advantage to repel the shootings of pain, and the impulses of appetite. Thus, love and joy, leave behind them a succession of pleasurable and fervent emotions, which, settling into habit, still continue to diminish the influences of sense upon the elastic spirit.

In all these instances, the power of the mind over sensation is, if at all, but imperfectly *voluntary*. The passions are often excited, without the previous energy of the will. They rise from sudden and unexpected causes. But the question before us was principally intended to ask—"Whether the mind has a *direct* and " *immediate* power of diminishing sensation, by " its *mere volition*. Can it, by its *own energy*, " summon a degree of strength and elasticity, " which shall, in any measure, lessen the per- " ception of sensitive feeling!"

Numerous instances seem to prove the affirmative. For how many persons have, with the full view of pain and suffering before them, resolved to brave their utmost rage; and, by means of that resolution, have really suffered much less than they would otherwise have done? How many, who have enjoyed composure and calmness amidst the severest tortures? The examples of Mutius Scævola, and of Portia, are well known. In both, the mind seems to exert a degree of *direct* controul over the sense of pain, and

and by its own volitions so far to weaken it, as to endure, with apparent calmness, what would to many appear impossible for human nature to support.

We smile, indeed, at the pompous and unnatural grimace of an old Stoic, crying out, "O pain, I will never acknowledge thee to be an evil." The attempt to annihilate, or to despise sensation, is doubtless much too high; and, in this degree, borders upon frenzy. But ought we not, at the same time, to admire the heroism of a mind struggling to maintain its liberty, its peace, its self-command, and endeavouring to arm itself, by rational and moral influences, against the tyranny of appetite, and of sense? And would not this Stoic, who, convinced that it was in his power not to be overcome, is resolutely determined not to yield, feel less pain, than one, who, with a puny and timid spirit, endeavours to fly from the enemy whom he dares not meet? Would not this be the case with the hardy Spartan, in whom

" Generous scorn

" Of pain, or danger, taught his early strength

" To struggle patient with severest toils!"*

The instances of the firm endurance of torture, in the North American Indians, would be absolutely incredible, if not supported by testimony,

* Glover's *Leonidas*, book. I. l. 540

which

which we cannot dispute, without the most ridiculous scepticism. If their sensations were originally equal to ours, one is ready to say, it would be impossible to acquire that apathy, which they discover in such dreadful circumstances. Let us, then, ascribe something to natural temperament, to climate, to habit. But shall we not, also, ascribe something to the manner, in which they have been accustomed to prepare themselves for such a scene? Does not the idea, inculcated upon them from their earliest infancy, that it is cowardly to betray any marks of fear, or to utter any complaint, tend to stiffen the mind against the perception of pain, and to produce some part, at least, of this astonishing insensibility?

The Gentlemen of the Faculty, who are present, could doubtless produce many striking facts, in which the resolute energy of the mind has manifested its power over corporeal feeling. One instance, to which many of them were witnesses, they will recollect with pleasure. An old soldier, at the Manchester Infirmary, was a few years ago cut for the stone. During that dreadful operation, he uttered no complaint, but appeared calm, and chearful; and, as soon as it was over, insisted a long time upon “walking to his apartment, *for the honour of an old soldier.*” Did not that sense of honour stupify, in some degree, the sense of pain, by inspiring that

that heroism and valour, which are the soldier's highest characters on the field of battle?

Let us behold a Spanish Devotee, upon some solemn occasion, lashing his bare back through the streets with a severity, which almost covers him with blood; and, when in the presence of his mistress, redoubling his strokes with astonishing fury, seeming to feel a glow of conscious triumph in proportion to the number of his stripes, and the violence of his pain. Or, let us turn our eye to the dreadful penances, incredible fastings, and unmerciful austerities, which enthusiasts of all ages, countries, and religions, have voluntarily endured, and which, thus sanctified and sweetened by folly, they have seemed hardly to feel. Who can deny, that some power resides in the will, of tempering and diminishing corporeal sensibility?

If such is the power of *false* religion, we shall justly expect a still stronger and nobler influence from that which is *true*: nor shall we be disappointed. History teems with instances of those, who, in the cause of heaven, have manifested a firmness, a sublimity, a heroism of soul—I had almost said, worthy of their cause. What glorious and animating spectacles have been seen, of men, of women, even of young persons, meeting agony and death, in every form of horror which cruel superstition could invent, with a serenity, yea, even with a cheerfulness
of

of soul, which indicated, which demonstrated, the sentiment we are now endeavouring to support! We deny not the peculiar aid and presence of heaven, in those moments. But we also maintain, that the spirit of true religion, at all times a rational, a calm, a manly spirit, tends of itself to diminish the influence of sense, and consequently to sheath the pungency of sensation.

Mental strength, like that of the body, depends in no small degree, upon habit. He who has never been accustomed to exert the authoritative dominion of his will over his senses, will be puny and tender. The calls of appetite will be, to him, imperious and irresistible. Whilst the man, who has been used to deny these calls, will, with comparative ease, endure the absence of sensitive good, and the presence of sensitive suffering. Hence, the superior fortitude with which many of the weaker sex, whose frames seem to be naturally more irritable to pain, endure the most dreadful operations. And hence too, that superior patience, which mankind often acquire from the long endurance of affliction.

But, whatever judgment we may form upon this question, as to the *direct* and *immediate* power of the will over the perceptions of sense, —its *indirect* and *mediate* influences cannot be disputed. Whenever we can divert the thoughts
to

to the other subjects, or excite passions of different natures, both of which are certainly, in some degree, in the power of the mind, we so far lessen the pangs of corporeal pain. The mere diversion of thought, by whatever means, is of great use. It is probable, that the mind cannot receive two perceptions at the same instant. Every moment, therefore, of such diversion, is a pause from suffering. Or, if it be admitted that they may be isochronous, yet the effect of the one, if of a different kind, will be to diminish the other. If, indeed, both the perceptions be of the same nature; if, to the torture of bodily pain, be added the distress of mental anguish; the one, compounding itself with the other, will exceedingly increase the sensibility. Compare the feelings of a person, suffering under some violent disease, from the consequences of his own guilt—with those of another person, suffering the same affliction, for the testimony of a good conscience, in the cause of liberty, or virtue!

When sensation is acute, thought will not easily be diverted. A stronger gale of affection, or of passion, will be necessary to turn it from its course. And we have already said, that passions of every kind, whilst they continue in their strength, are able to produce this effect. For the moment, there is little difference between joy and sorrow, anger or fondness. The sudden

sudden coming in of a friend long unseen, or an alarm for his safety, if we saw him in the instant of danger, will equally suspend corporeal feeling. The tooth-ach shall fly away, at the presence of the operator, or at the tidings of some happy event. A man, in the paroxysms of rage, shall be as insensible to wounds and pain, as the pious martyr at the stake.

But let us pass on beyond the moment of vehement excitation, and then, how great the difference! Among the passions, we must, first, distinguish those which are of the longest continuance; because these will produce the longest, and consequently the greatest, effects. Anger and fear are short-lived impulses. And, when their violence is spent, they induce languor and depression. Hence, though sensation may be suspended by them for a moment, it will soon return with double pungency. On the contrary, love, joy, and hope are passions which live longer in the human breast, which leave behind them a firm and animating feeling, and which, therefore, may be expected to produce effects more lasting and important.

Again, we may distinguish those passions, which center themselves in a narrower, from those which expand to a wider, circle—the selfish, from the generous and sublime. Those of the former class, after their first agitation, are so far from blunting the sense of pain, that they irritate

ritate and increase it. Thus, fear, and sorrow, turn the mind inward upon itself, and aggravate all its painful sensibilities. Anger, which partakes of the nature of fear and of grief, and is, like them, selfish, has the same consequences. It makes the mind sore, and irritable, and thus whets the edge of suffering. Love and gratitude, on the other hand, center the heart on other objects; and, if those objects are great, and amiable, and worthy, inspire sublimity and strength. Thus, during their whole continuance, they render the mind less passively the slave of bodily impression. What has not parental affection done, what has it not endured, for the support and defence of its offspring? How amazingly, how long, has it defied danger, and despised suffering, in such a cause! What has not the love of country voluntarily consented to endure!

The sublimest feelings which can govern the human heart, are those inspired by Religion. For religion carries the soul beyond itself, and centers all its strongest affections upon our Creator, and a better world. If these be properly, that is, habitually felt, they will be most friendly to that self-possession, which braces the mind in all its best, and most lasting energies. These feelings are permanent in their nature, and large in their object. And how wonderful are often their effects! In that most awful hour of dissolving nature, when the body is racked with
expiring

expiring agonies, faith and hope have often presented the most astonishing spectacles of fortitude, yea even of triumph! The mind, borne upwards towards its Maker, has been able to smile in pangs, and to exult in dissolution.

The moral influence of this sentiment is highly interesting and important to us all. It furnishes an argument in favour of virtue and religion, too considerable to be passed over in silence. For goodness, not only inspires the purest satisfactions, both in the present moment, and in future reflection, but it actually lessens the degree of bodily suffering. It not only increases the mental enjoyment, but it diminishes corporeal pain. It not only administers the sweetest consolations under disease, but it renders the disease itself less afflictive.

Born into a world exposed to sorrow, and inhabiting bodies liable every moment to various sufferings, of what value is it, to have our minds in a condition able to sustain, and even to mitigate the sharpness of corporeal feeling! Of what importance, to possess a spirit firm, vigorous, manly! And of what moment, to act under the direction of those principles, and under the impulse of those affections, which tend to produce self-possession, and inward strength!

In order to this, it will be necessary to cultivate the habit of self-command. It will be

proper to accustom the will to a dominion over sense. And it will be wise to cherish those affections, which carry the mind beyond itself, to objects permanent and noble.

Stoicism, which affected to secure to its votaries an exemption from evil, and which, in order to this, denied that corporeal pain deserved the name, not only took its aim too high, but omitted the proper means of achieving what it is possible to attain. It enjoined resolute self-denial. It established the dominion of mind over sense. But it did not expand, or elevate the passions to their noblest objects. Hence, it failed in its effect. For it will follow from what has been observed, that a mind which would be firm, must be humble. Pride may be indeed a lasting passion—but it is selfish. And there are many moments in the present life, when the high sense of dignity must yield to humiliating circumstances, to the consciousness of weakness, and of ill desert.

But the nobler passions, which we have before mentioned, improve by time, and meliorate by habit. The soul, whose better affections are centered upon proper objects, increases in inward strength; it is better fortified against distress and pain; and it is ripening for a world, where pain and anguish shall annoy it no more for ever.

A NARRATIVE of the Sufferings of a COLLIER, who was confined more than seven Days, without SUSTENANCE, and exposed to the CHOKE-DAMP, in a COAL-PIT not far from MANCHESTER; with OBSERVATIONS on the Effects of FAMINE; on the Means of alleviating them; and on the Action of FOUL AIR on the HUMAN BODY. By THOMAS PERCIVAL, M. D. F. R. S. and S. A. &c.

JANUARY 6, 1785.

IN compliance with the request of this Society, I have obtained an authentic account of the case of the unfortunate man, who was so long confined in a coal-pit at Hurst, near Ashton-under-line. My information, concerning him, has been communicated by Mr. John Lees, of Clarksfield, in that neighbourhood, a Gentleman of probity and good sense, who himself very humanely assisted the poor sufferer, and collected in person, or received from those who attended him till his death, the intelligence with which he has favoured me.

On Saturday the fourth of December, 1784, about eight o'clock in the morning, Thomas

Travis, a collier, aged twenty-seven, descended into the pit at Hurst, which is ninety yards in depth; and several other workmen were in readiness to follow him. But soon after he had reached the bottom, the sides of the pit fell in, and he was cut off from all supplies of the external air. The quantity of earth was so large, that it required six days to remove it: And, on Thursday, when the passage was compleated, the foulness of the vapours prevented any one, for some time, from venturing into the works. On Friday, several men entered the coal-mine; but not finding Travis, they conjectured that he had attempted to dig his way into another pit, at no great distance. They followed him by the traces of his working; and on Saturday afternoon, about four o'clock, he heard them, and implored their speedy assistance. When they reached him, he was laid upon his belly, and raising his head, he looked at the men, and addressed one of them by his name. But his eyes were so swollen and protruded, that they were shocked with the appearance of them; and they prevailed upon him to suffer a handkerchief to be tied round his head, assigning, as a reason, that the light might prove dangerous and offensive to him. Sal volatile was then held to his nostrils, and soon afterwards he complained of the handkerchief, and desired them to remove it. They complied

complied with his request; but his eyes were then sunk in their sockets, and he was unable to distinguish the candle, though held directly before him. Nor did he ever afterwards perceive the least glimmering of light. He asked for something to drink; and was supplied with water gruel, that had been previously provided, of which he took a table spoonful, every ten or fifteen minutes. When the men first discovered him, his hands and feet were extremely cold, and no pulse could be felt at the wrist. But after he had tasted the gruel, and smelled at the sal volatile, the pulsation of the artery became sensible, and grew stronger when they had rubbed him, and covered him with blankets. He now complained of pain in his head and limbs, and said, his back felt as if it had been broken. Two men lay by his sides, to communicate warmth to him; he put his hands into their bosoms; expressed his sense of its being comfortable; and slept, when he was not roused to take nourishment. In this situation he remained several hours, till they had completed a road for his conveyance out of the pit. Whilst they were carrying him, he had a motion to make water and to go to stool, but had not sufficient power to accomplish either. At one o'clock on Sunday morning, he was brought to his own house; put into bed, well covered, and fed with chicken broth. But his weakness

rendered him indifferent to nourishment. He continued to doze and sleep; and notwithstanding his pulse seemed at first to increase in vigour, it became quick about five o'clock, when he warned them of his approaching end, and expired, without a struggle, in a few minutes. Though Travis had been asthmatic for many years, his respiration was remarked to be clear and easy, under the circumstances above described. He remained perfectly sensible till his death; but had no accurate idea of the duration of his confinement in the pit; For on being interrogated concerning this point, he estimated the time to have been only two days, yet added, that he thought those days were very long.

As the foregoing account is defective in some interesting particulars, I have applied to Mr. Lees for further information; and shall lay before the Society the Substance of the answers, which he has returned to my several queries.

1. I enquired, what food Travis had taken, during the space of twenty-four hours, before he went into the coal-pit; and have been informed, that, on Friday morning, he eat a mess of water pottage and milk, to his breakfast; had roasted beef and potatoes to his dinner; broth and pudding to his supper; and on the Saturday morning, just before his descent
into

into the coal-mine, a cup of broth and a piece of bread and cheese.

2. It is not known whether he had any evacuations in the coal-pit, no marks of them having been discovered.

3. There is no doubt that he could see, at the time when he was found, as he gave assurances of it to the men, notwithstanding the tumefaction and protrusion of his eyes.

4. The compass of the cavity which he had dug, and where he was laid upon his belly, at the time when the men reached him, was three yards in length, and two in width. The stratum of coal is about two feet thick. There was a communication between the place where he was confined, and another pit. But as the passage was eighty yards long, and in no part more than eight or ten inches wide, the mouth of the pit also, into which he had descended, being stopped, and the body of earth, through which he had dug, thrown behind him, no circulation of air could possibly take place. And the truth of this conclusion is evinced by the state of the air, in the other pit, to which this passage led. For it was there so foul as to extinguish the candles, which the workmen carried down, in order to come at Travis, by the way which they denominate, the *air gate*.†

5. The

† The ventilation of this subterranean passage might, perhaps, have been expedited, and the *mephitic* almost instantly

5. The temperature of the air varies much in coal-pits, even of the same depth. No thermometrical observations were made on the present occasion; but the sensations of Travis seem to have indicated coldness; and his extremities never recovered their natural warmth. Moisture always abounds in these mines.

6. The weakness of Travis prevented him from giving any account of his sufferings, either from hunger or thirst. But it was observed that he was eager to drink, at the time when he was found.

7. It is certain that Travis had no provisions with him, in the coal-mine; and that there was not any supply of water, except near the mouth of the pit; a place he must immediately have quitted, and to which he deprived himself of the power of returning, by throwing the earth behind him, in his progress. We may therefore presume, that he passed the whole seven days of his confinement, without either meat or drink.

instantly corrected, by carrying down into it buckets of water, and slaking in them a sufficient quantity of fresh burnt quicklime. The hot steam, generated by this operation, it may be presumed, would have diffused itself quickly through the whole cavity; the gas would have united with the aqueous vapour; been precipitated with it; and a current of atmospheric air would have rushed in to supply its place.

This

This affecting catastrophe coincides, in a striking manner, with an observation of Hippocrates, *That most of those, who neither eat nor drink for seven days, die within that period. And that though they survive, so as afterwards to take nourishment, their former fasting will prove fatal to them.** Yet it is evident, that the remark, of this faithful recorder of facts, was founded on experience too limited, to give it validity. For we have many well attested accounts of longer continued abstinence, without destruction to life. Sir William Hamilton, in his narrative of the earthquakes in Italy, A.D. 1783, mentions a girl, of sixteen years of age, who remained eleven days without food, under the ruins of a house at Oppido. She had a child in her arms, five or six months old, who died the fourth day. A light, through a small chasm, enabled her to ascertain the time of her confinement, and she gave a very clear relation of her sufferings. When Sir William Hamilton saw her, she did not appear to be in bad health, drank easily, but with difficulty swallowed any thing solid.† In cases of this kind, is it not probable that the body may be supplied with fluids from the external air, by the exertion of some extraordinary powers in the lymphatic

* Hippocrat. de Carnibus. Sect. III.

† Philosophical Transactions, vol. LXXIII. p. 169.

system? Thus the Negro, mentioned by Dr. Chalmers, who was gibbeted at Charlestown, in March 1779, and had nothing given him afterwards, regularly voided every morning, till he died, a large quantity of urine.* The spring season, in South Carolina, is attended with great nocturnal dews, which being imbibed by the pores of the skin, furnished the poor Negro with a superabundance of fluids in the night, and a sufficiency to support perspiration in the day. I visited, not long since, in consultation with her kinsman Dr. Eason, an elderly lady, who laboured under a very severe lientery. Her evacuations, as often happens both in this disease and in the diabetes, far exceeded in quantity, the liquids which she swallowed, or what could be ascribed to the dissolution of her solids. During five or six days before her death, she took no aliment whatever, and only occasionally moistened her mouth, by putting her fingers into it, after they had been dipped in water. Yet she discharged a pint of urine once in twenty-four hours. I am inclined to conjecture, that the moisture of the coal-pit was favourable to Travis; but how long he might have subsisted under such circumstances, it is not possible to determine. It may however be presumed, that his death was rather accelerated than retarded,

* Chalmers on Fevers, p. 2.

by the changes and the hurry which he underwent.

In famine, life may be protracted with less pain and misery, by a moderate allowance of water. For the acrimony and putrefaction of the humours are obviated by such dilution, the small vessels are kept permeable, and the lungs are furnished with that moisture, which is essential to the performance of their functions. Fantonus, a writer of respectable authority, in the estimation of Morgagni, relates the history of a woman, who obstinately refused to take any sustenance, except twice, during the space of fifty days, at the end of which period she died.* But he adds, that she used water, by way of drink, though in small quantity. Redi, who made many experiments, (cruel and unjustifiable in my opinion) to ascertain the effects of fasting on fowls, observed, that none were able to support life beyond the ninth day, to whom drink was denied; whereas one, indulged with water, lived more than twenty days.

Hippocrates has observed, that children are more affected by abstinence than young persons; these, more than the middle aged; and the middle aged, more than old men. Agreeably to this aphorism, Dante is said, by his countryman Morgagni, to have framed the incidents in

* Morgagni de Sedibus et Causis Morborum; Epist. 27.

the affecting story of Count Ugolino, a nobleman of Pisa, who was confined, with his four sons, in the dungeon of a tower; the key of which being cast into the river Arno, they were, in this horrible situation, starved to death. And they are represented by the poet, as dying at different periods, according to their respective ages.* Travis, being in the prime of life, was fitted to bear the extremities of want better than he could have done in the state of adolescence, when the body calls for constant nutriment, to support its growth. But of what he felt we are left in uncertainty, as he declined, through weakness, to give any relation of it. There are constitutions, which do not suffer much pain from the calls of hunger. I have been informed,

* On reviewing the story of Count Ugolino, as related by Dante, in his thirty-third Canto, I find that Morgagni is mistaken in supposing the incidents of it conformable to the observation of Hippocrates. Nor is the poet to be condemned, as deviating from truth or nature; because the power to endure famine must depend no less upon the state of health and strength, than on the age of the sufferer. The following lines are copied from the translation of this Poem, by the Earl of Carlisle.

Now the fourth morning rose ; my eldest child
Fell at his father's feet, in accent wild,
Struggling with pain, with his last fleeting breath,
“ Help me, my fire,” he cried, and sunk in death.
I saw the others follow one by one,
Heard their last scream, and their expiring groan,

by

by a young physician from Geneva, that, when he was a student at Montpelier, he fasted three nights and four days, with no other refreshment than a pint of water daily. His hunger was keen, but never painful, during the first and second days of his abstinence; and the two following days, he perceived only a faintness, when he attempted either bodily or mental exertion: A sense of coldness was diffused over his whole frame, but more particularly affected the extremities. His mind was in a very unusual state of pusillanimity; and he experienced a great tendency to tears, whenever he recollected the circumstance, which had been the occasion of his fasting. During the whole period, the alvine excretions were suppressed, but not those by the kidney. And at the close of it, his skin became tinged with a shade of yellow. The first food he took was veal broth, which had something of an intoxicating effect, producing a glow of warmth, and raising his spirits, so as to render him ashamed of his despondency. Perhaps in the case of Sextius Baculus, as recorded in the Commentaries of Cæsar, * the extraordinary courage and prowess which he suddenly exerted, might be aided by the exhilarating effect of sustenance, which, under such circumstances, it is probable he would no longer decline. The fact however evinces, that neither his sickness nor the

* De Bello Gallico, lib. VI.

sensations of hunger had been so violent, as much to impair his strength of body or vigour of mind. Pomponius Atticus, the celebrated friend of Cicero, who put a voluntary end to his life in the seventy-seventh year of his age, by refusing all food, appears to have experienced ease from his disorder, rather than any acute sufferings by famine.† From the former circumstance it has been conjectured, that he did not wholly deny himself the use of water, or of some other diluent. But though a few examples of this kind may be adduced, we have the evidence of numerous melancholy facts to shew, that the pressure of want is agonizing to the human frame. “I have talked,” says an ingenious writer, “with the captain of
 “a ship, who was one of six, that endured it in
 “its extremity, and who was the only person that
 “had not lost his senses, when they received accidental relief. He assured me his pains, at first,
 “were so great, as to be often tempted to eat
 “a part of one of the men who died, and which
 “the rest of his crew, actually for some time, lived
 “upon: He said, that during the continuance of
 “this paroxysm, he found his pains insupportable,
 “and was desirous, at one time, of anticipating
 “that death, which he thought inevitable: But

† Sic cum biduo cibo se abstinuisset. subito febris decessit, leviorque morbus esse cepit: tamen propositum nihilo fecius peregit. Itaque die quinto, postquam id consilium inierat, decessit. Corn. Nepos in Vit. Pomp. Attic.

“ his pains, he said, gradually decreased, after the
“ sixth day, (for they had water in the ship, which
“ kept them alive so long,) and then he was in
“ a state rather of langour, than desire ; nor did
“ he much wish for food, except when he saw
“ others eating ; and that for a while revived his
“ appetite, though with diminished importunity.
“ The latter part of the time, when his health was
“ almost destroyed, a thousand strange images rose
“ upon his mind ; and every one of his senses be-
“ gan to bring him wrong information. The most
“ fragrant perfumes appeared to him to have a fetid
“ smell ; and every thing he looked at took a
“ greenish hue, and sometimes a yellow. When
“ he was presented with food by the ship’s com-
“ pany, that took him and his men up, four of
“ whom died shortly after, he could not help
“ looking upon it with loathing instead of desire ;
“ and it was not, till after four days, that his sto-
“ mach was brought to its natural tone ; when
“ the violence of his appetite returned, with a sort
“ of canine eagerness.” *

To those who, by their occupations, are exposed to such dreadful calamities, it is of serious importance to be instructed in the means of alleviating them. The American Indians are said to use a composition of the juice of tobacco, and the shells of snails, cockles, and oysters calcined,

* See Goldsmith’s *History of the Earth*, vol. II. p. 126.

whenever

whenever they undertake a long journey, and are likely to be destitute of provisions. It is probable, the shells are not burnt into quicklime, but only so as to destroy their tenacity, and to render them fit for levigation. The mass is dried, and formed into pills, of a proper size to be held between the gum and lip, which, being gradually dissolved and swallowed, obtund the sensations both of hunger and of thirst. Tobacco, by its narcotic quality, seems well adapted to counteract the uneasy impressions, which the gastric juice makes on the nerves of the stomach, when it is empty : And the combination of testaceous powders with it may tend to correct the secretion that is supposed, by an eminent anatomist, to be the chief agent in digestion, and which, if not acid, is always united with acidity.† Certain at least it is, that their operation is both grateful and salutary ; for we find the luxurious inhabitants of the East Indies mix them with the betle nut, to the chewing of which they are universally and immoderately addicted. Perhaps such absorbents may be usefully applied, both to divide the doses, and to moderate the virulence of the tobacco. For, in the internal exhibition of this plant, much caution is required, as it produces sickness, vertigo, cold clammy sweats, and a train of other formidable symptoms, when taken in too

† See Mr. John Hunter's paper, on the digestion of the stomach after death. *Philos. Transact.* for 1772.

large a quantity. During the time of war, the impressed sailors frequently bring on these maladies, that they may be admitted into the hospitals, and released from servitude. It would be an easy and safe experiment to ascertain the efficacy, and to adjust the ingredients of the Indian composition which I have mentioned. And I am inclined to believe, that the trial would be, in some degree, successful, because I have repeatedly experienced, in the course of my professional practice, that smoking tobacco gives relief, in those habitual pains of the stomach, which appear to arise from the irritation of the gastric secretions. The like effect is sometimes produced by increasing the flow of saliva, and swallowing what is thus discharged.† And I have elsewhere related the case of a Gentleman, who used to masticate, many hours daily, a piece of lead, which, being neither hard, friable, nor offensive to the palate, suited his purpose, as he thought, better than any other substance. He continued the custom many years, deriving great ease from it, and suffering no sensible injury from the poisonous quality of the metal. On mentioning this fact to a navy surgeon, he acquainted me, that the sailors, when in hot climates, are wont to mitigate thirst, by roll-

† A lady, in this neighbourhood, was relieved of a chronic pain in the stomach, by chewing *amara dulcis*, after various other remedies had failed: And I have seen good effects from the *calamus aromaticus*, used in the same way.

ing a bullet in their mouths. A more innocent mean might be devised; but the efficacy of this evinces, that the salivary glands are for a while, capable of furnishing a substitute for drink. When a scarcity of water occurs at sea, Dr. Franklin has advised, that the mariners should bathe themselves in tubs of salt-water: For, in pursuing the amusement of swimming, he observed that, however thirsty he was before immersion, he never continued so afterwards; and that, though he soaked himself several hours in the day, and several days successively, in salt-water, he perceived not, in consequence of it, the least taste of saltiness in his mouth. He also further suggests, that the same good effect might perhaps be derived from dipping the sailor's apparel in the sea; and expresses a confidence that no danger of catching cold would ensue.

To prevent the calamity of famine at sea, it has been proposed, that the powder of *Salep* should constitute part of the provisions of every ship's company.† This powder, and portable soup, dissolved in boiling water, form a rich thick jelly; and an ounce of each of these articles furnishes one day's subsistence to a healthy full grown man. Indeed, from the experiments which I have made on *Salep*, I have reason to believe the supposition well founded, that it contains more nutritious matter, in proportion to its bulk, than any

† Lind on the Diseases of Hot Climates.

Other vegetable production, now used as food. § It has the property, also, of concealing the nauseous taste of salt water ; and consequently may be of great advantage at sea, when the stock of fresh water is so far consumed, that the mariners are put upon short allowance. By the same mucilaginous quality, it covers the offensiveness, and even, in some measure, corrects the acrimony, of salted and putrescent meats. But, as a preservative against hunger, Salep would be most efficacious, combined with an equal weight of beef suet. By swallowing little balls of this lubricating compound, at proper intervals, the coats of the stomach would be defended from irritation: And as oils and mucilages are highly nutritive, of slow digestion, and indisposed to pass off by perspiration, they are peculiarly well adapted to support life, in small quantities. This composition is superior in simplicity, and perhaps equal in efficacy, to the following one, so much extolled by Avicenna, the celebrated Arabian physician ; to whom we are indebted for the introduction of rhubarb, cassia, tamarinds, and fenna, into the *Materia Medica*. “ Take sweet almonds, and beef suet, of each one pound ; of the oil of violets two ounces ; and of the roots of marsh mallows one ounce: Bray these ingredients together, in a mortar, and form the mass into boluses, about the size of a common nut.”

§ See the Author's *Essays Medical and Experimental*, vol. II.

Animal fat is singularly powerful in assuaging the most acute sensations of thirst; as appears from the narrative of the sufferings experienced by those, who were confined in the black hole at Calcutta. A hundred and forty-six persons, exhausted by fatigue and military duty, were there thrust together into a chamber of eighteen cubic feet, having only two windows, strongly barred with iron, from which, in a close sultry night, and in such a climate as that of Bengal, little or no circulation of fresh air could be enjoyed. In a few minutes, these unhappy wretches fell into so profuse a perspiration, that an idea can hardly be formed of it; and this was succeeded by a raging thirst, which increased in proportion as the body was drained of its moisture. Water! Water! became the universal cry; and an old soldier on the outside, through pity, furnished them with a few skinfulls of it. But these scanty supplies, like sprinklings on the fire, served only to feed and increase the flame. From this experience of its effects, Mr. Holwell, their chief, determined to drink no more; and kept his mouth moist, by sucking the perspiration out of his shirt sleeves, and catching the drops as they fell from his head and face. You cannot imagine, says he, how unhappy I was, if any of them escaped me. He came into the prison without his coat, the season being too hot to bear it: And one of his
miserable

miserable companions, observing the expedient he had hit upon, of allaying his thirst, robbed him, from time to time, of a considerable part of his store. This plunderer, whom he found to be a young Gentleman in the service of the East India Company, afterwards acknowledged, that he owed his life to the many comfortable draughts, which he derived from him. Before Mr. Holwell adopted this mode of relief, he had attempted, in an ungovernable fit of thirst, to drink his own urine: But it was so intensely bitter, that a second taste could not be endured; whereas, he assures us, no Bristol water could be more soft and pleasant than his perspiration. || And this, we may presume, consisted chiefly of animal fat, melted by excessive heat, and exuding from the cellular membrane, through the pores of the skin.

Persons who have been accustomed to animal food, are soon reduced, when supplied only with the farinacea. Several years ago, to determine the comparative nutritive powers of different substances, an ingenious young physician, of my acquaintance, made a variety of experiments on himself, to which he unfortunately fell a sacrifice. I have been informed, that he lived a month upon bread and water, and that, under this regimen of diet, he every day diminished much in his weight. But last winter, a student

of physic at Edinburgh, confined himself, for a longer space of time, to a pint of milk, and half a pound of white bread daily: And he assures me, that he passed through the usual labours of study and exercise, without feeling any decay of health or strength, and without any sensible loss of bulk † The cutaneous, urinary, and alvine excretions were very scanty during the whole period; and the discharge of fæces occurred only once in a week. In this case, the oily and coagulable parts of the milk probably furnished a larger proportion of aliment, and at the same time contributed to check the waste, by perspiration and other discharges. For oleaginous substances are retained long in the body, by their viscosity. Dr. Ruffel, in his *Natural History of Aleppo*, relates, that in those seasons when oil abounds, the inhabitants, by indulgence in it, are disposed to fever, and affected with infarctions of the lungs; maladies which indicate both retention and obstruction. Milk has been suspected, by some, of producing similar effects, though in a slighter degree; and the free use of it has been, on this account,

† The following facts, cited by Haller, shews the powers of milk, in small quantities, to support life; but does not ascertain how far it supplies or obviates the waste of the body. *Lactis in diem libra, tres feminae, à nivis ruinâ obrutæ per 37. dies vitam sustentarunt.* HALLER. ELEMENT. PHYSIOLOG. vol. VI. p. 255.

forbidden to asthmatics. From my own personal experience I should presume, that it is commonly much longer in passing by the kidneys, than other liquids; and analogy would lead us to the same conclusion, concerning its influence on perspiration.

Gum arabic might be a good substitute for salep, in the composition, which I have recommended. And as it will give such firmness to the mass, as to require manducation, the saliva, by this means separated and carried into the stomach, would further contribute to assuage the sensations both of hunger and of thirst. We are informed, by a traveller of veracity, that the Abyssinians take an annual journey to Cairo, to sell the products of their country; and that, as they pass over vast deserts, the duration of their rout is no less uncertain than a voyage at sea. In the year 1750, the caravan had consumed all their provisions, and were under the necessity of searching amongst their merchandize, for something wherewith to support life, under that extremity. They found a sufficient stock of gum arabic; and more than a thousand persons subsisted upon it solely, for the space of two months. The caravan arrived in safety at Cairo, without having sustained any extraordinary losses, either by hunger or disease.† This gum, combined with sugar and the whites of eggs, has

† *Hasselquist's Voyages in the Levant*, p. 298.

been lately extolled in France, under the name of PATTIGUMO, as a remedy for catarrhal de-fluxions. I have seen cakes made of these ingredients, and think they might very well be applied to the purpose of obviating hunger. They are not perishable in the hottest climates, may be carried about the person with convenience, and though very tough, are pleasant to the taste. In the formula by which they are made, the proportion of sugar is too large, and that of gum arabic too small, if the mass be intended to assuage the cravings of appetite. According to my information, the receipt is as follows. Take of fine sugar four ounces, and of gum arabic one ounce: Levigate them well together, and add half an ounce of rose water, and of the whites of eggs a sufficient quantity.

In our attempts to recover those who have suffered under the calamities of famine, great circumspection is required. Warmth, cordials, and food are the means to be employed; and it is evident that these may prove too powerful in their operation, if not administered with caution and judgment. For the body, by long fasting, is reduced to a state of more than infantile debility; the minuter vessels of the brain, and of the other organs, collapse for want of fluids to distend them; the stomach and intestines shrink in their capacity; and the heart languidly vibrates, having scarcely sufficient energy to pro-

pel the scanty current of blood. Under such circumstances, the treatment of Travis was proper, with respect to the application of heat, by placing on each side a healthy man in contact with him. *Pediluvia* or fomentations might, also, have been used with advantage. The temperature of these should be lower than that of the human body, and gradually increased, according to the effects of their stimulus. New milk, weak broth, or water gruel ought to be employed both for the one and the other, as nutriment may be conveyed into the system, this way, by passages, probably the most pervious in a state of fasting, if not too long protracted. "A lad at New-market, a few years ago, having been almost starved, in order that he might be reduced to a proper weight, for riding a match, was weighed at nine o'clock in the morning, and again at ten; and he was found to have gained near thirty ounces in weight, in the course of an hour, though he had only drank half a glass of wine in the interval. The wine probably stimulated the action of the nervous system, and incited nature, exhausted by abstinence, to open the absorbent pores of the whole body, in order to suck in some nourishment from the air."* But no such absorption, as this, can be expected, in a state of

* Bishop Watson's Chemical Essays, vol. III. p. 101.

extreme weakness and emaciation, gradually induced; 'because the lymphatics must partake of the general want of tone and energy. And notwithstanding the salutary effects of wine, in the case of the jockey, who, it is likely, had been reduced by sweating as well as by abstinence, such a stimulant might prove dangerous, and even fatal to one in the situation of Travis. I should, therefore, advise the exhibition of cordials in very small doses, and, at first, considerably diluted. Slender wine whey will perhaps best answer this purpose; and afford, at the same time, an easy and pleasant nourishment. When the stomach has been a little strengthened, an egg may be mixed with the whey, or administered under some other agreeable form. The yolk of one was, to Cornaro, sufficient for a meal. And the narrative of this noble Venetian, in whom a fever was excited by the addition of only two ounces of food to his daily allowance, shews, that the return to a full diet should be conducted with great caution, and by very slow gradations.

Though, I fear, my commentary has been already extended to an undue length, yet I cannot close it, without soliciting the attention of the Society, to one additional circumstance, in the case of Travis, peculiarly interesting in its consequences; viz. the ease with which he breathed, for a considerable space of time, air too

too impure for candles to burn in, and which the men, who went in search of him, durst not venture to inspire. As he had been long asthmatic, we may reasonably conclude, from his suffering so little, that the commonly received opinion of the *suffocating* nature of the mephitic or choak-damp, that it destroys the elasticity of the air, and occasions a collapſion of the lungs, is without foundation, notwithstanding all the respectable authorities, which may be advanced in support of it. Indeed, from the *phenomena* which attend the extinction of life, in those to whom such vapours have proved mortal, it is evident, that the poison acts chiefly on the nervous system. The vital principle seems to be arrested, and almost instantaneously destroyed; sometimes even without a struggle, and, possibly, without any antecedent pain. Pliny the elder was found, after the fatal eruption of Mount Vesuvius, exactly in the same posture in which he fell, with the appearance of one asleep, rather than dead: *Habitus corporis quiescenti quam defuncto similior*. * Some persons killed by foul air in a cellar at Paris, were stiff as statues, with their eyes open, and in the posture of digging. † M. Beaumè relates the history of a man, who was recovered from apparent death, produced by a similar cause, and who asserted, that he had felt neither

* Plinii Epist. 16. lib. VI.

† Bonaire Dict. d'Histoire Naturelle.

pain nor oppression; but that at the point of time when he was losing his senses, he experienced a delightful kind of delirium. * If, under such circumstances, this person could be sufficiently collected to notice his feelings, the testimony is decisive, that *oppression* was not one of them; and consequently, that he could not suffer from *suffocation*. And the account receives some confirmation from what Dr. Heberden says, in his lectures on poisons, that he had seen an instance, in which the fumes of charcoal brought on the same delirium, which hen-bane, and other intoxicating vegetables produce. Abbè Fontana breathed a certain portion of inflammable air, not only without inconvenience, but with unusual pleasure. He had a facility in dilating the breast, and never felt an equally agreeable sensation, even when he inhaled the purest dephlogisticated air. But he suffered greatly from this gratification, in a subsequent experiment: For, having filled a bladder with about three hundred and fifty cubic inches of inflammable air, he began to breathe it boldly, after discharging the atmospheric air, contained in his lungs, by a violent expiration. The first inspiration produced a great oppression: Towards the middle of the second, he was observed to become very pale, and objects appeared confused to his eyes: Nevertheless, he made a third inspiration. His

* Rozier. Observations de la Physique, Jan. 1, 1774.

strength now failed, he lost his sight entirely, fell upon his knees, and soon afterwards upon the floor. His respiration continued to be effected with difficulty and pain, as if he had a weight upon his breast; and he did not perfectly recover before the succeeding day. *

In this instance, some degree of palsy was probably induced, in the nerves of the lungs, by the sudden action of concentrated inflammable air, conveyed into the vesicles, forcibly emptied of atmospheric air. For in ordinary respiration, about thirty-five cubic inches of air are inhaled and exhaled; but in a violent expiration, the air discharged may amount to sixty cubic inches. † In the case of Travis, it will be remembered, that the air was sufficiently salubrious, when he went down into the coal-pit; that by stagnation it became gradually noxious; and that his nervous system must therefore have been progressively habituated to its influence. This is conformable to the observations of my friend Dr. Priestley, who discovered, that if a mouse can bear the first shock of being put into a vessel, filled with artificial gas, or if the gas be increased by degrees, it will live, a considerable time, in a situation which would prove instantly fatal to other mice. And he frequently noticed, that when a number of mice had been confined,

* Philosophical Transactions, vol. LXIX, p. 346.

† Ibid. p. 349.

in a given quantity of infected air, a fresh mouse introduced amongst them, has presently died in convulsions.

The same ingenious philosopher seems to have ascertained, that respiration is a phlogistic process; that it is the office of the lungs to carry off the putrid *effluvium*, or to discharge the phlogiston, introduced into the system with the aliment, and become effete; and that the air we breathe acts, on this occasion, as a *menstruum*. We are also assured, by an able chemist, that the quantity of air, phlogisticated by a man in a minute, is equal to that, which is phlogisticated by a candle in the same space of time.* Hence it might be presumed, that like supplies of atmospheric air are essential to respiration and combustion. But the experience of Travis proves the fact to be otherwise.† And though miners generally try the salubrity of the subterraneous air, by the test of a lighted candle, yet we are informed by Mr. Keir, that he has seen them working in the shaft of a coal-pit, several yards below that part where the candle was extinguished. Indeed it was observed by Mr. Boyle, and has since been confirmed by Dr. Priestley, that an animal will live nearly, if not

* See Crawford on Animal Heat, p. 80.

† Dr. Priestley informs me, that he has lately bestowed particular attention on a kind of air, in which a candle burns, but in which a mouse will not live.

quite,

quite, as long in air, in which candles have burned out, as in common air. There must be some power, therefore, it should seem, in the living œconomy, to free the body from redundant phlogiston, by other emunctories than the lungs: or a small portion of atmospheric air may suffice, for this purpose, in extraordinary emergencies, and for a short period of time. This accommodating faculty, if I may so express it, is evidenced in various other instances, and particularly in one, no less remarkable than that, of which we are now treating: I mean, the equality of temperature, which the body retains, in great extremes of heat and cold. A Russian Boor, in the winter season, daily experiences all these varieties of air, of heat, and of cold, without inconvenience. When labouring out of doors, he is exposed to the intensity of frost and snow: When he retires in the evening, to his hut, which consists only of one close apartment, never ventilated during six months, he feeds upon salted fish or flesh, and afterwards reposes on a greasy mattress, placed over an oven, in which billets of wood are burned. In this situation, he is literally stewed, with his whole family, who live in a constant steam, not offensive to themselves, but so gross and noisome, as to be scarcely supportable by a stranger. *

* See Phil. Transf. vol. LXVIII. p. 622.

The atmosphere of a crowded town must, in many respects, nearly resemble the foul air of a Russian cottage. Yet thousands enjoy in it a tolerable share of health, though we admit the truth of the poet's description, as well as the propriety of his counsel to the delicate and valetudinary;

Ye who, amid this feverish world, would wear
A body free of pain, of cares a mind;
Fly the rank city, shun its turbid air;
Breathe not the chaos of eternal smoke,
And volatile corruption, from the dead,
The dying, sickening, and the living world,
Exhaled, to fully heaven's transparent dome
With dim mortality.*

It has been found, by experiment, that the fumes emitted by almost every species of burning fuel, are fatal to animals, when applied in a sufficiently concentrated state. I have computed, that three hundred tons of coal are every day consumed, in the winter season, at Manchester. The factitious gas, generated by its combustion, must amount at least to one third of this quantity; it is probable that the smoke, proceeding from it, constitutes another third part; and both together are capable of occupying a space of very wide extent. Now if it were not for the dispersion of these vapours by wind, the precipitation of them by rain, and the influence

* Armstrong on Health, Book I.

of other causes, which restore salubrity to the air, respiration could not be carried on, under such circumstances. And we may observe that frosty weather, which is generally serene and without wind, always proves extremely oppressive, and sometimes even fatal to asthmatic patients, in great cities. Indeed the rate of human mortality bears a pretty near proportion to their magnitude and population: And I have shewn, in another work, § that there is an astonishing difference between the expectation of life in Manchester, and the country immediately surrounding it, although the inhabitants of both are subject to the same vicissitudes of weather, carry on the same manufactures, are supplied with provisions from the same market, and by their free intercourse, are almost equally liable to attacks of small-pox, fevers, and other epidemics.

It is evident, therefore, that habit, however it may abate, cannot entirely counteract the baneful operation of bad air. And those will feel its pernicious effects most strongly, in every situation, whose nervous systems are endued with more than ordinary sensibility. Such persons I would caution not to indulge their curiosity in the inspection of unwholesome manufactures, nor in visiting mines, caverns, stoves, hospitals, or prisons. Several Gentlemen, in this assembly,

§ *Essays Philosophical, Medical and Experimental.*

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will

will recollect that the late Dr. Brown suffered, in a very acute degree, by accompanying two foreigners of distinction into the duke of Bridgewater's works, at Worsley. It happened they were the first, who entered the tunnel, on that day. The candles, which they carried with them, were observed to burn very dimly; but neither the passengers nor the boatmen experienced any difficulty in respiration. After remaining in the coal pits a considerable time, they proceeded to Warrington; where Dr. Brown was attacked with violent pains, which shifted suddenly from one part of his body to another. Small purple spots overspread his skin; his throat became so tumefied as to render swallowing difficult; and great prostration of strength, with a low fever ensued. The doctor was subject to the anomalous gout, had once a paralytic complaint of long continuance, and hence we may conclude that his nervous system was endued with peculiar irritability. He was not, however, the sole sufferer; for one of the foreigners was affected with similar petechiæ, but attended with little pain or disorder.

Last year a general alarm was spread, in this neighbourhood, concerning the danger, arising from the noisome effluvia of certain cotton works, to all employed, or who had communication with those employed in them. But the good sense and humanity of the proprietors, aided
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by the authority and patriotic exertions of our magistrates, have quieted these apprehensions, by removing, in no inconsiderable degree, the causes from which they originated. * And, I trust, the

* The following Paper, printed and distributed by the order of the Magistrates, will shew the Measures taken on this interesting occasion.

C O U N T Y O F L A N C A S T E R.

A representation, of a very alarming nature, having been made by Lord Grey de Wilton, and a great number of the most respectable inhabitants of the township and neighbourhood of Radcliffe, in this county, to the gentlemen to whom the following letter is directed, of a malignant fever, which was supposed to have originated in the cotton-works there; they took the liberty of desiring Dr. Percival, and the other Medical Gentlemen of Manchester, to take upon themselves the trouble of making such enquiries, as they should think necessary, in order to ascertain the causes to which it was owing; and the most proper methods to be used, to prevent the further spreading of the contagion. Much to the credit of the physicians, they undertook the task with the greatest alacrity; went over to the infected place themselves; and the following report was the consequence.

To	SAMUEL CLOWES, jun.	} Esquires.
	THOMAS B. BAYLEY,	
	DORNING RASBOTHAM,	
	AND	
	M. BENTLEY,	

His Majesty's Justices of the Peace, for the County Palatine of Lancaster.

the factories are now tolerably well ventilated, supplied with purer oil, and kept in a state of greater cleanliness. Still, however, the delicate
and

GENTLEMEN,

We have taken into the most deliberate consideration, your very humane and judicious requisition; and we shall now lay before you the result of our inquiries, concerning those interesting objects, which you have proposed to our investigation. We have fully satisfied ourselves, either from actual observation, or authentic testimony, that a low, putrid fever, of a contagious nature, has prevailed many months in the cotton mills, and amongst the poor, in the township of Radcliffe. We cannot, however, ascertain, whether this fever originated in those works, or was imported into Radcliffe from some other parts of the county. But though this point remain doubtful, we are decided in our opinion—That the disorder has been supported, diffused, and aggravated, by the ready communication of contagion to numbers crowded together; by the accession to its virulence from putrid effluvia; and by the injury done to young persons through confinement, and too long continued labour; to which several evils the cotton-mills have given occasion.

These evils, we trust, are not without remedy; and from the benevolent attention, which the proprietors of the Radcliffe-works have shewn to the sick and infirm under their charge, we may reasonably presume to hope, they will be induced to adopt the following practical regulations, from motives of policy, humanity, and justice, as well as from the respect, which is due to your authority.

I. All the casements of the windows, and the three large western doors of the cotton-mills, should be left open every night: The same regulation should take place, during the recess from work, at noon; and as many casements should be

and valetudinary incur a risque in visiting them. For foul air, though it contain not any contagious particles, may yet possess a virulence, that is capable, in particular habits, of producing fever. Like certain poisons, it effects
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be kept open, in the hours of labour, as may be compatible with carrying on the operations of the machinery.

II. The casements are too small; being in dimension, only about one sixth part of the window. They are likewise placed high, and parallel to each other—a position obviously unfavourable to complete ventilation: for the inlet of the air ought to be lower than the outlet.

III. Several fire-places, with open chimnies, should be erected, at proper distances, in each work room. The stoves, now employed, afford no sufficient passage for the offensive vapours generated in the rooms; and increase the contamination of the air, by the effluvia which they emit. Turf would be the cheapest, and also a very salutary fuel; for it consists, chiefly, of the roots of vegetables; and yields, in burning, a strong, penetrating, and pungent smoke, which is likely to prove as good an antidote to contagion, as that of wood is found to be, from long experience.

IV. The rooms should be daily swept, and the floors washed, at least once every week, with strong lime-water or with water impregnated with the spirit of vitriol, or the acid of tar. The walls and ceilings may be scraped and whitewashed, at first, every month, and afterwards, twice or thrice yearly. Lime fresh burnt, and as soon as it is slaked, must be used for this purpose, and the wash laid on whilst it is hot.

V. During the prevalence of the present fever, the apartments, should be fumigated weekly with tobacco.

an instantaneous change in the nervous system, by which the organs of secretion are disturbed, and the secretions themselves corrupted. The common precautions, therefore, ought not to be neglected by those who expose themselves to the influence of such vapours. The valetudinary,

Brimstone would, perhaps, be more powerful, but, in burning, it yields an acid, which might be injurious to the cotton.

VI. Great attention ought to be paid to the privies. They should be washed daily; and ventilated in such a manner, that the smell arising from them, shall not be perceptible in the work-rooms.

VII. The rancid oil, which is employed in the machinery, is a copious source of putrid effluvia. We apprehend, that a purer oil would be much less unwholesome, and that the additional expence of it would be fully compensated, by its superior power in diminishing friction.

VIII. A strict observance of cleanliness should be enjoined on all who work in the mills, as an efficacious mean of preventing contagion, and of preserving health. It may also be adviseable to bathe the children occasionally. The apparel of those who are infected with the present fever, should be well fumigated, before it is again worn. And the linen, &c. of the sick, should first be washed in cold water, lest the steams arising from heat communicate the distemper to the persons engaged in that operation. Croster's lye, when it can be procured, is preferable to water. The bodies of those who die of the fever, should be closely wrapped in pitched cloth; and interred as soon as propriety or decency will permit. Smoking tobacco will be an useful preservative to the superintendants of the works, and to others exposed to infection, who can practise it with convenience.

ry, especially, should not enter the works with an empty stomach, should previously fortify themselves by a glass or two of wine, and counteract the sedative operation of the putrid miasms by the stimulus of hartshorn, eau de luce, or camphorated vinegar, applied to the nose.

IX. We earnestly recommend a longer recess from labour at noon, and a more early dismissal from it in the evening, to all who work in the cotton-mills. But we deem this indulgence essential to the present health, and future capacity for labour, of those who are under the age of fourteen. For the active recreations of childhood and youth are necessary to the growth, the vigour, and the right conformation of the human body. And we cannot excuse ourselves, on the present occasion, from suggesting to you, who are the guardians of the public weal, this further very important consideration, that the rising generation should not be debarred from all opportunities of instruction, at the only season of life, in which they can be properly improved.

We have the honour to be, with the highest respect,

GENTLEMEN, your most faithful,
and obedient humble servants,

THOMAS PERCIVAL, M. D.
JOHN COWLING, M. D.
ALEXANDER EASON, M. D.
EDWOOD CHORLEY, M. D.

MANCHESTER,
October 8, 1784.

P. S. Our respectable colleagues, Dr. Mainwaring and Dr. Mitchell, are absent from Manchester at this time.

nose. But these volatile substances are to be suffered, as much as possible, to rise spontaneously, and not to be drawn forcibly into the nostrils: For by such inhalation the noxious atoms, floating in the air, will be conveyed to the olfactory nerves, with additional energy; and, being lodged in the schneiderian membrane, they may exert their baneful powers, when, the action of the antidote shall cease. To this cause is to be ascribed that permanency of offensive smells, which makes us sensible to their impression, some time after our removal from their source. And, when this impression is no longer perceived, in the ordinary course of respiration, it may often be renewed by that effort which we denominate snuffing. In this way, I apprehend, and not solely from absorption, the fact is to be explained which Mr. Howard has related, that his phial of vinegar, after using it in a few prisons,

Manchester Michaelmas Sessions, 1784.

The magistrates of this county, assembled in their general quarter sessions at Manchester, impressed with the obligations they are under, have directed the clerk of the peace to give their public thanks to Dr. Percival, Dr. Cowling, Dr. Eason, and Dr. Chorley; and to take care that their letter shall be printed and distributed, so that every part of the community may receive the benefit of their salutary admonitions, a strict attention to which is most earnestly recommended by the court. By order of the court,

JAMES TAYLOR,

Deputy-clerk of the peace for the county of Lancaster,

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became intolerably disagreeable to him. When a malignant contagion prevails in hospitals, goals, or parish work-houses, it is to be feared that the preventives, I have recommended, will afford no adequate security. They may, however, be of some avail: and it would surely be rashness and presumption to neglect them altogether. But firmer grounds of confidence may reasonably influence the minds of those, who are led by official or professional duty to incur such dangers. “ I have been frequently “ asked,” says the humane writer whom I have just quoted, and with whose words I shall now close this commentary, “ what precautions I “ use to preserve myself from infection, in the “ prisons and hospitals which I visit. I here “ answer, that next to the free goodness and “ mercy of the Author of my being, temperance “ and cleanliness are my preservatives. Trusting “ in *Divine Providence*, and believing myself in “ the way of my *duty*, I visit the most noxious “ cells; and, while thus employed, I *fear no “ evil.*” *

* Howard on Prisons, p. 431, 8vo. 1780.

RESULT *of some* OBSERVATIONS *made by* BENJAMIN RUSH, M. D. PROFESSOR of CHEMISTRY in the University of PHILADELPHIA, *during his Attendance as* PHYSICIAN GENERAL of the MILITARY HOSPITALS of the UNITED STATES, *in the late* WAR. *Communicated by* Mr. Thomas Henry, F.R.S. &c. *Read* October 5, 1785.

To Mr. THOMAS HENRY.

DEAR SIR,

THE inclosed observations are at your service. Instead of diluting them with theories and cases, which would add only to the number of books, but not to the stock of facts, I send them to you in as short a compass as possible. They are not so fit for the public eye as I could wish; but if you think them worthy of a place in your Transactions, you are welcome to them.

Be assured, Dear Sir, of the great regard of

Your friend and humble servant,

BENJAMIN RUSH.

PHILADELPHIA, July 22, 1785.

RESULT

RESULT of OBSERVATIONS, &c.

1. The principal diseases were putrid fevers. Men, who came into the hospitals with pleurisies, rheumatisms, &c. soon lost the types of their original diseases, and suffered, or died, with the putrid fever.
2. This putrid fever was often artificial, produced by the want of sufficient room and cleanliness.
3. It always prevailed most, and with the worst symptoms, in winter: a free air, which could only be obtained in summer, always prevented or checked it.
4. Soldiers, billeted in private houses, escaped it, and generally recovered soonest from all their diseases.
5. Convalescents, and drunken soldiers, were most exposed to putrid fevers.
6. The remedies that appeared to do most service in this disease, were tartar emetic in the beginning, gentle doses of laxative salts, bark, wine, (two or three bottles a day in many cases) and sal volatile.
7. In all those cases where the contagion was received, cold seldom failed to render it active. Whenever an hospital was removed in winter, one half of the patients generally sickened in the way, or soon after their arrival at the place to which they were sent.
8. The

8. The army, when it lay in tents, was always more sickly, than when it lay in the open air: it was always more healthy, when kept in motion, than when it lay in an encampment.

9. Militia officers, and soldiers, who enjoyed health during a campaign, were often seized with fevers upon their return to the *Vita Mollis*, at their respective homes. There was one instance of a militia captain, who was seized with convulsions the first night he lay on a feather bed, after lying several months on a matraß and on the ground. The fever was produced by the sudden change in the manner of sleeping, living, &c. It was prevented, in many cases, by the person lying, for a few nights after his return to his family, on a blanket before the fire.

10. I met with several instances of bubos, and ulcers in the throat, as described by Dr. Don. Monro: they were mistaken by some of the junior surgeons for venereal sores, but they yielded to the common remedies of putrid fevers.

11. Those patients in putrid fevers, who had large ulcers, and even mortifications on their backs or limbs, generally recovered.

12. There were many instances of patients in putrid fevers who, without any apparent symptoms of dissolution, suddenly fell down dead, upon being moved; this was more especially the case, when they arose to go to stool.

13. Those

13. Those officers, who wore flannel shirts, or waistcoats next to their skin, in general escaped fevers, and diseases of all kinds.

14. Lads under twenty years of age, were subject to the greatest number of camp diseases.

15. The southern troops were more sickly, than the northern or eastern troops.

16. The native Americans were more sickly, than the Europeans.

17. Men above thirty and thirty-five years of age were the hardiest soldiers in the army. Perhaps this was the reason, why the Europeans were more healthy, than the native Americans; they were more advanced in life.

18. The troops from Maryland, Virginia, and North Carolina, sickened for the want of salt provisions. Their strength and spirits were only to be restored to them by means of salt bacon. I once saw a private in a Virginia regiment throw away his ration of choice fresh beef, and give seven shillings and six-pence specie for a pound of salt meat.

19. Most of the sufferings, and mortality in our hospitals, were occasioned not so much by actual want or scarcity of any thing, as by the ignorance, negligence, &c. in providing necessities for them. After the *purveying*, and *directing* departments were separated (agreeably to the advice of Dr. Monro) in the year 1778, very few of the American army died in our hospitals.

A P P E N -

A P P E N D I X.

EXTRACT FROM THE MINUTES OF THE SOCIETY.

WEDNESDAY MAY 11, 1785.

THOMAS PERCIVAL, M.D. &c. IN THE CHAIR.

The following REGULATIONS were read:

“ **T**HAT a gold medal, of the value of seven guineas, be given to the author of the best experimental paper, on any subject relative to Arts and Manufactures, which shall have been delivered to the Secretaries, and read at the ordinary meetings of the Society, before the last Wednesday in March 1785.

“ That the adjudication of this premium be referred to the committee of papers; that their decision shall be made by ballot; and that the medal shall be delivered, by the president, to the person to whom it shall have been adjudged, or to his representative.

“ That

“ That if the person, to whom the medal shall have been adjudged, be not one of the Society, his name shall be enrolled in the list of honorary members.

“ To encourage the exertions of young men, who attend the meetings of the Society as visitors, That a silver medal, of the value of one guinea be given to any one of them, under the age of twenty-one years, who shall within the year, have furnished the Society with the best paper on any subject of literature or philosophy; and that such adjudication shall be made by the committee of papers.

After these Regulations had been read, the President thus addressed the Society;

GENTLEMEN,

In consequence of the resolutions, which have now been read, I am called upon officially to give you information, that the gold medal has been unanimously adjudged to Edward Hufsey Delaval, Esq. for his *Experimental Inquiry into the cause of the permanent colours of opaque bodies*: And that the silver medal has, with the same unanimity, been assigned to Mr. Thomas Henry, Jun. for his *Review of the Controversy between Henry Cavendish, Esq. F. R. S. and Richard Kirwan, Esq. F. R. S.*

F. R. S. relative to the cause of the diminution of common air, in phlogistic processes.

I congratulate you on the satisfaction which you must feel, from these pleasing and honourable testimonies of the benefits resulting from our institution. We have established a Society which, in its views, combines practice with speculation; and unites, with the culture of science, the improvement of the arts. Cast your eyes on the list of communications, which have been recited and discussed in this assembly, and you will clearly perceive the variety, extent; and importance of the objects, which our establishment comprehends. It was my wish and intention to have drawn, from that list, a systematic retrospect of the progressive advances we have made in philosophy and literature. But the short space of a fortnight, to one, occupied as I am, with numerous and pressing engagements, is inadequate to such an undertaking. And I must content myself with offering to your candid attention, the Review of Mr. Delaval's Memoir, which I have delivered, for perusal, to the secretary.

An epitome of Mr. Delaval's Memoir being then read, the President, after the conclusion, addressed the two successful candidates, in the following terms.

ADDRESS

A D D R E S S

TO MR. CHARLES TAYLOR.

AS the representative of Mr. Delaval, whose distance precludes his personal attendance, on the present occasion, I deliver to You, in the name of the Literary and Philosophical Society, this Medal, the most distinguished mark of approbation, which we have to bestow. To merit the honours of Science, and of the Arts, is a just and noble object of ambition; and to confer them, I am persuaded, is, at this instant, felt both as a privilege and a pleasure, by the members of our Institution.

When you transmit to Mr. Delaval the well earned reward of his desert, let it be accompanied with an earnest request, that he will prosecute the researches, he has so happily begun; and that he will communicate to this Society the further discoveries, which his industry and ingenuity may accomplish.

TO MR. THOMAS HENRY, JUNIOR.

FROM a sage in philosophy, who is above my praise, I turn, with cordial satisfaction, to

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one,

one, whose proficiency in the knowledge of nature reflects a lustre on his youth. And I present to You, in the name of this Society, the honourable mark of distinction, which has been unanimously adjudged to your merit. To foster rising genius; to incite the spirit of emulation; and to give energy to the powers of the human mind, by calling them forth into early exertion, are amongst the most important objects of our Institution. And I cannot better fulfil my official duty, than by indulging the friendly feelings of my heart, in urging you to perseverance, industry, and ardour in the pursuits of science. Copy the fair example which Heaven, with peculiar favour, has set before you; elevate your ambition to the true dignity and perfection of your nature; and in every study extend your views to the final designation of your faculties, which are not limited to this transitory scene, but must here be trained for Immortality.

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ERRATA.

“ The writer of the ‘ Essay on Crimes and Punishments ’ begs
“ leave to correct a glaring anachronism, which has inadvertently
“ escaped him in note †, page 330. In comparing the Feudal and
“ Papal systems, nothing more was meant, than to point out
“ their striking resemblance in the article of mulcts ; whereas the
“ turn of the expression seems to imply, that *civil* mulcts, which
“ had their origin in the earliest Saxon times, were copied from the
“ *spiritual* indulgence granted by the Romish church, which was
“ one of its latest corruptions.”

* * * *As the Editors reside at a distance from the
Press, many Errors may probably escape their notice,
which the Authors of the several Papers will have
the candour to excuse.*

20 D. Blue







